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ELEMENTS OF ANATOMY.

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ELEMENTS OF ANATOMY

BY

JONES QUAIN, M.D.

Sixth Edition

V. Mott

EDITED BY

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AND

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PROFESSORS OF ANATOMY AND PHYSIOLOGY IN UNIVERSITY COLLEGE, LONDON.

IN THREE VOLUMES

ILLUSTRATED WITH NUMEROUS ENGRAVINGS ON WOOD.

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ADVERTISEMENT.

THE subjoined Advertisement will explain the extensive changes which this work underwent in its Fifth Edition, and indicate the manner in which the task of carrying them out was apportioned between the Editors. In the present edition no fundamental change has been made in the book, but the whole has been subjected to careful revision, and such alterations and additions have been introduced as the progress of the science appeared to require.

The increasing claims of professional duty having prevented Mr. Quain from continuing his services as co-editor, his place has been taken by Mr. Ellis, who has accordingly been associated with Dr. Sharpey in preparing the present edition, and has edited that portion of the work which had previously fallen to the share of his predecessor.

UNIVERSITY COLLEGE, LONDON,
October, 1856.

[redacted]

ADVERTISEMENT TO THE FIFTH EDITION.

Soon after they had begun to prepare for publication a new edition of Dr. Quain's Anatomy, the Editors found that in order to place the work on a level with the existing state of anatomical knowledge, and maintain for it the character it has hitherto possessed, their labour must be much more extensive than usually falls to the lot of an editor. They perceived, in fact, that it would be advisable to write a considerable part of the work anew, whilst the rest underwent such alterations as were required in a careful revision. The following changes have accordingly been made in the present edition.

The whole of the Section on General Anatomy is re-written. This division has been paged separately in order that a portion of it might appear in each of the Parts into which the work was divided in its publication.

The Descriptive Anatomy of the Osseous System has undergone various alterations, and some portions, including those which treat of the Formation and Growth of the several Bones of the Skeleton, belong exclusively to this edition. The description of the Articulations has been subjected to a complete revisal.

Under the head of the Muscular System, many additions have been made; among which may be especially mentioned the account of the variations of form and attachment observed in individual muscles. Several parts have been re-written; but the paragraphs headed "Dissection" and "Action of Muscles" are printed from the preceding edition with scarcely any alteration.

The principal changes to which the section on the Vascular System has been subjected, occur in the description of the Arteries. The history of each of the largêr arteries has been recast, and a statement of the varied forms which these vessels present in different cases has been abridged from a special treatise published by one of the Editors.

In the remainder of the work, including the description of the Brain, Nerves, and Organs of the Senses, the Heart, with the Digestive, Respiratory, Urinary, and Generative Organs, little or nothing remains of the former editions.

The Surgical Anatomy, which has been introduced partly in connection with the history of the principal arteries and partly at the end of the work, has likewise been written for the present edition.

In editing the work, the different parts have been apportioned in the following manner, viz., the General Anatomy to Dr. Sharpey, with the Descriptive Anatomy of the Brain, the Heart, the Organs of Respiration, Voice, Digestion, Urine and Generation; and to Mr. Quain the remaining portion of the Descriptive Anatomy, comprehending the Bones, Muscles, Articulations, Fasciæ, Vessels, Nerves, and Organs of the Senses, as well as the Surgical Anatomy of the different Regions.

In a part of their labours, the Editors have availed themselves of the aid of their Junior Colleagues in the Anatomical Department of University College, viz., Mr. Ellis, the late Mr. Potter, and Mr. Marshall.

The Description of the Nerves is, in great part, due to Mr. Ellis, who has devoted much attention to the prosecution of this branch of Anatomy. Mr. Potter afforded his aid in the account of the Fasciæ and Organs of Sense. By the assistance of Mr. Marshall, Dr. Sharpey has been relieved of much of the labour required for the execution of his share of the Descriptive Anatomy; in the preparation of which, while free use has been made of existing systematic works, the notes of his lectures have, for the most part,

served as a basis. But while they willingly concede to their colleagues a full share of any merit which may be found in those portions of the work in which they were respectively engaged, the Editors assume to themselves the whole of the responsibility.

A large number of Engravings on wood have been added to those which appeared in preceding editions. When copied from any other work, the sources from which the new Illustrations have been derived are in all cases mentioned; when no such acknowledgment is made, the drawing is to be considered original.

Lastly, it may be well to explain, that when statements are made in the first person, they proceed from the Editor of that part of the book in which they occur.

September, 1848.

CONTENTS OF THE FIRST VOLUME.

ELEMENTS OF ANATOMY.

INTRODUCTION.

THE material objects which exist in nature belong to two great divisions; those which are living or which have lived, and those which neither are nor have ever been endowed with life. The first division comprehends animals and plants, the other mineral substances. Division of natural bodies.

In a living animal or plant, changes take place and processes are carried on, which are necessary for the maintenance of its living state, or for the fulfilment of the ends of its being; these are termed its functions, and certain of these functions being common to all living beings serve among other characters to distinguish them from inert or mineral substances. Such are the function of *nutrition*, by which living beings take extraneous matter into their bodies and convert it into their own substance, and the function of generation or *reproduction*, by which they give rise to new individuals of the same kind, and thus provide for the continuance of their species after their own limited existence shall have ceased.

But in order that such processes may be carried on, the body of a living being is constructed with a view to their accomplishment, and its several parts are adapted to the performance of determinate offices. Such a constitution of body is termed organisation, and those natural objects which possess it are named *organised bodies*. Animals and plants, being so constituted, are organised bodies, while minerals, not possessing such a structure, are *inorganic*.

The object of anatomy, in its most extended sense, is to ascertain and make known the structure of organised bodies. Object of Anatomy.
But the science is divided according to its subjects; the

investigation of the structure of plants forms a distinct study under the name of Vegetable Anatomy, and the anatomy of the lower animals is distinguished from that of man or human anatomy under the name of Comparative Anatomy.

Organs and textures.

On examining the structure of an organised body, we find that it is made up of members or organs, through means of which its functions are executed, such as the root, stem, and leaves of a plant, and the heart, brain, stomach, or limbs of an animal; and further, that these organs are themselves made up of certain constituent materials named tissues or textures, as the cellular, woody, and vascular tissues of the vegetable, or the osseous, muscular, areolar, vascular, and various others, which form the animal organs.

Most of the textures occur in more than one organ, and some of them indeed, as the areolar and vascular, in nearly all, so that a multitude of organs, and these greatly diversified, are constructed out of a small number of constituent tissues, just as many different words are formed by the varied combinations of a few letters; and parts of the body, differing widely in form, construction, and uses, may agree in the nature of their component materials. Again, as the same texture possesses the same essential characters in whatever organ or region it is found, it is obvious that the structure and properties of each tissue may be made the subject of investigation apart from the organs into whose formation it enters.

General and Descriptive Anatomy.

These considerations naturally point out to the Anatomist a twofold line of study, and have led to the subdivision of Anatomy into two branches, the one of which treats of the nature and general properties of the component textures of the body; the other treats of its several organs, members, and regions, describing the outward form and internal structure of the parts, their relative situation and mutual connection, and the successive conditions which they present in the progress of their formation or development. The former is usually named "General" Anatomy, the latter "Special" or "Descriptive" Anatomy.*

* These names have been objected to, and the terms Histology (ἱστὸς, a web, and λόγος, a discourse), and Morphology (μορφὴ, form, &c.), themselves not free from objection, have been proposed in their stead: there seems no sufficient reason for the substitution; the latter term, indeed, is often used in a different sense; the former is now, however, gaining acceptance, both in this country and elsewhere.

GENERAL ANATOMY.

GENERAL CONSIDERATIONS ON THE TEXTURES.

Enumeration of the textures.

The human body consists of solids and fluids. Only the solid parts can be reckoned as textures, properly so called; still, as some of the fluids, viz. the blood, chyle, and lymph, contain in suspension solid organised corpuscles of determinate form and organic properties, and are not mere products or secretions of a particular organ, or confined to a particular part, the corpuscles of these fluids, though not coherent textures, are to be looked upon as organised constituents of the body, and as such may not improperly be considered along with the solid tissues. In conformity with this view the textures and other organised constituents of the frame may be enumerated as follows:—

The blood, chyle, and lymph.
Epidermic tissue, including epithelium, cuticle, nails, and hairs.
Pigment.
Adipose tissue.
Areolar or connective tissue.
Fibrous tissue.
Elastic tissue.
Cartilage and its varieties.
Bone or osseous tissue.
Muscular tissue.
Nervous tissue.
Blood-vessels.
Absorbent vessels and glands.
Serous and synovial membranes.

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Mucous membranes.
Skin.
Secreting glands.
Vascular or ductless glands.

Organic systems.

Every texture taken as a whole was viewed by Bichat as constituting a peculiar system, presenting throughout its whole extent in the body characters either the same, or modified only so far as its local connections and uses rendered necessary; he accordingly used the term "organic systems" to designate the textures taken in this point of view, and the term has been very generally employed by succeeding writers. Of the tissues or organic systems enumerated, some are found in nearly every organ; such is the case with the areolar or connective tissue, which serves as a connecting material to unite together the other tissues which go to form an organ; the vessels, which convey fluids for the nutrition of the other textures, and the nerves, which establish a mutual dependence among different organs, imparting to them sensibility, and governing their movements. These were named by Bichat the "general systems." Others again, as the cartilaginous and osseous, being confined to a limited number, or to a particular class of organs, he named "particular systems." Lastly, there are some tissues of such limited occurrence that it has appeared more convenient to leave them out of the general enumeration altogether, and to defer the consideration of them until the particular organs in which they are found come to be treated of. Accordingly the tissues peculiar to the crystalline lens, the enamel of the teeth, and some other parts, though equally independent textures with those above enumerated, are for the reason assigned not to be described in this part of the work.

General and particular or local systems.

It is further to be observed, that the tissues above enumerated are by no means to be regarded as simple structural elements; on the contrary, many of them are complex in constitution, being made up of several more simple tissues. The blood-vessels, for instance, are composed of several coats of different structure, and some of these coats consist of more than one tissue. They are, strictly speaking, rather organs than textures; and indeed it may be remarked, that the distinction between textures and organs has not in general been strictly attended to by anatomists. The same remark applies to mucous membrane and the tissue of the glands, which structures, as commonly understood, are

highly complex. Were we to separate every tissue into the simplest parts which possessed assignable form, we should resolve the whole into a very few constructive elements; and, having regard to form merely, and not to difference of chemical constitution, we might reduce these elements to the following, viz. 1. *simple fibre*, 2. *homogeneous membrane*, either spread out or forming the walls of tubes or *cells*, and 3. *globules* or *granules*, varying in diameter from the $\frac{1}{12000}$th to the $\frac{1}{6000}$th of an inch. These, with a quantity of *amorphous matter*, homogeneous or molecular, might be said, by their varied combinations, to make up the different kinds of structure which we recognise in the tissues; and if we take into account that the chemical nature of these formative elements and of the amorphous matter may vary, it will be readily conceived that extremely diversified combinations may be produced.

Elements of structure.

PHYSICAL PROPERTIES.

The animal tissues like other forms of matter are endowed with various physical properties, such as consistency, density, colour, and the like. Of these the most interesting to the Physiologist is the property of imbibing fluids, and of permitting fluids to pass through their substance, which is essentially connected with some of the most important phenomena that occur in the living body, and seems indeed to be indispensable for the maintenance and manifestation of life.

All the soft tissues contain water, some of them more than four-fifths of their weight; this they lose by drying, and with it their softness and flexibility, shrinking up into smaller bulk and becoming hard, brittle, and transparent; but when the dried tissue is placed in contact with water, it greedily imbibes the fluid again, and recovers its former size, weight, and mechanical properties. The imbibed water is no doubt partly contained mechanically in the interstices of the tissue, and retained there by capillary attraction, like water in moist sandstone or other inorganic porous substances; but it has been questioned whether the essential part of the process of imbibition by an animal tissue is to be ascribed to mere porosity, for the fluid is not merely lodged between the fibres or laminæ, or in the cavities of the texture; a part, probably the chief part, is incorporated with the matter which forms the tissue, and is in a state of union with it, which is supposed to be more intimate than could well be ascribed to the mere inclusion of a fluid in the pores of another substance. Be this as it may, it is clear that the tissues, even in their inmost substance, are permeable to fluids, and this property is indeed necessary, not only to maintain their due soft-

as known, are peculiar to living bodies, and are accordingly named "vital properties." These vital properties are called into play by various stimuli, external and internal, physical, chemical, and mental; and the assemblage of actions thence resulting has been designated by the term "life." The words "life" and "vitality" are often also employed to signify a single principle, force, or agent, which has been regarded as the common source of all vital properties, and the common cause of all vital actions.

Assimilative property.

1. Of the vital properties, there is one which is universal in its existence among organised beings, namely, the property, with which all such beings are endowed, of converting into their own substance, or "assimilating," alimentary matter. The operation of this power is seen in the continual renovation of the materials of the body by nutrition, and in the increase and extension of the organised substance, which necessarily takes place in growth and reproduction; it manifests itself, moreover, in individual textures as well as in the entire organism. It has been called the "assimilative force or property," "organising force," "plastic force," and is known also by various other names. But in reality the process of assimilation produces two different effects on the matter assimilated: first, the nutrient material, previously in a liquid or amorphous condition, acquires determinate form; and secondly, it may, and commonly does, undergo more or less change in its chemical qualities. Such being the case, it seems reasonable, in the mean time, to refer these two changes to the operation of two distinct agencies, and, with Schwann, to reserve the name of "plastic" force for that which gives to matter a definite organic form; the other, which he proposes to call "metabolic," being already generally named "vital affinity." Respecting the last-named agency, however, it has been long since remarked, that although the products of chemical changes in living bodies for the most part differ from those appearing in the inorganic world, the difference is nevertheless to be ascribed, not to a peculiar or exclusively vital affinity different from ordinary chemical affinity, but to common chemical affinity operating in circumstances or conditions which present themselves in living bodies only.

Plastic and metabolic forces.

Vital contractility.

2. When a muscle, or a tissue containing muscular fibres, is exposed in an animal during life, or soon after death, and scratched with the point of a knife, it contracts or shortens itself; and the property of thus visibly contracting on the

application of a stimulus is named "vital contractility," or "irritability," in the restricted sense of this latter term. The property in question may be called into play by various other stimuli besides that of mechanical irritation—especially by electricity, the sudden application of heat or cold, salt, and various other chemical agents of an acrid character, and, in a large class of muscles, by the exercise of the will, or by involuntary mental stimuli. The stimulus may be applied either directly to the muscle, or to the nerves entering it, which then communicate the effect to the muscular fibre, and it is in the latter mode that the voluntary or other mental stimuli are transmitted to muscles from the brain. Moreover, a muscle may be excited to contract by irritation of a nerve not directly connected with it. The stimulus, in this case, is first conducted by the nerve irritated, to the brain or spinal cord; it is then, without participation of the will, and even without consciousness, transferred to another nerve, by which it is conveyed to the muscle, and thus at length excites muscular contraction. The property of nerves by which they convey stimuli to muscles, whether directly, as in the case of muscular nerves, or circuitously, as in the case last instanced, is named the "vis nervosa."

How excited.

"Vis nervosa."

The evidence that a tissue possesses vital contractility is derived, of course, from the fact of its contracting on the application of a stimulus. Mechanical irritation, as scratching with a sharp point, or slightly pinching with the forceps, electricity obtained from a piece of copper and a piece of zinc, or from a larger apparatus if necessary, and the sudden application of cold, are the stimuli most commonly applied. Heat, when of certain intensity, is apt to cause permanent shrinking of the tissue, or "crispation," as it has been called, which, though quite different in nature from vital contraction, might yet be mistaken for it; and the same may happen with acids and some other chemical agents, when employed in a concentrated state: in using such stimulants, therefore, care should be taken to avoid this source of deception.

Tests of vital contractility.

Sensibility.

3. We become conscious of impressions made on various parts of the body, both external and internal, by the faculty of sensation; and the parts or textures, impressions on which are felt, are said to be sensible, or to possess the vital property of "sensibility."

This property manifests itself in very different degrees in different parts; from the hairs and nails, which indeed are

is a property of the nervous system.

absolutely insensible, to the skin of the points of the fingers, the exquisite sensibility of which is well known. But sensibility is a property which really depends on the brain and nerves, and the different tissues owe what sensibility they possess to the sentient nerves which are distributed to them. Hence it is lost in parts severed from the body, and it may be immediately extinguished in a part, by dividing or tying the nerves so as to cut off its connection with the brain.

In estimating the degree of sensibility possessed by a tissue, whether in the human subject or by observations made on the lower animals, which for obvious reasons are much less satisfactory, several modifying circumstances must be taken into account, which will be duly adverted to in their proper place.

The sensorial function and vis nervosa, may be one and the same property.

It thus appears that the nerves serve to conduct impressions to the brain, which give rise to sensation, and also to convey stimuli to the muscles, which excite motion; and it is not improbable that, in both these cases, the conductive property exercised by the nervous cords may be the same, the difference of effect depending on this, that in the one case the impression is carried upwards to the sensorial part of the brain, and in the other downwards to an irritable tissue, which it causes to contract; the stimulus in the latter case either having originated in the brain, as in the instance of voluntary motion, or having been first conducted upwards, by an afferent nerve, to the part of the cerebro-spinal centre devoted to excitation, and then transferred to an efferent or muscular nerve, along which it travels to the muscle. If this view be correct, the power by which the nerves conduct sensorial impressions and the before-mentioned "vis nervosa" are one and the same vital property; the difference of the effects resulting from its exercise being due partly to the different nature of the stimuli applied, but especially to a difference in the susceptibility and mode of reaction of the organs to which the stimuli are conveyed.

DEVELOPMENT OF THE TEXTURES.

Original uniformity of structure.

The tissues of organised bodies, however diversified they may ultimately become, show a wonderful uniformity in their primordial condition. From researches which have been made with the microscope, especially during the last few years, it has been ascertained that the different organised structures found in plants, and, to a certain extent, also those of animals, originate by means of minute vesicles or cells. These cells, remaining as separate corpuscles in the fluids, and grouped together in the solids, persisting in some cases with but little change, in others undergoing a partial

Subsequent change.

or thorough transformation, produce the varieties of form and structure met with in the animal and vegetable textures. Nay, the germ from which an animal originally springs, so far at least as it has been recognised under a distinct form, appears as a cell; and the embryo, in its earliest stages, is but a cluster of cells produced from that primordial one; no distinction of texture being seen till the process of transformation of the cells has begun.

No branch of knowledge can be said to be complete; but there is, perhaps, none which can, at the present moment, be more emphatically pronounced to be in a state of progress than that which relates to the origin and development of the textures, and much of the current opinion on the subject is uncertain, and must be received with caution. In these circumstances, in order both to facilitate the exposition, and to explain to the reader more fully the groundwork of the doctrines in question, we shall begin with a short account of the development of the tissues of vegetables; for it was in consequence of the discoveries made in the vegetable kingdom that the happy idea arose of applying the principle of cellular development to explain the formation of animal structures, and they still afford important aid in the study of that, as yet, more obscure process.

OUTLINE OF THE FORMATION OF VEGETABLE STRUCTURE.

Elementary structure of vegetables.

When a thin slice from the succulent part of a plant is viewed under the microscope, it is seen to consist chiefly or entirely of a multitude of minute vesicles adhering together, of a rounded or angular form, and containing various coloured or colourless matters in their interior; these are the elementary cells (fig. 1′; fig. 2′, ¹ ²). These cells are so constructed that their walls are in close apposition, or are separated

Fig. 1′*.

* Nucleated cells from a bulbous root; magnified 290 diameters (Schwann).

only by an inter-cellular substance, which, according to Hugo von Mohl,* has so great a similarity to the substance of the cell-walls that it is impossible, even with the aid of chemical re-agents, to discover a line of demarcation between them. That eminent phytologist supposes that within what is commonly called the cell-wall there exists an extremely delicate membrane, constituting an interior vesicle, which he names the "Primordial utricle." This is in most cases so closely applied to the exterior wall as to be undistinguishable; but in young cells, and in those of strictly cellular plants, such as the Algæ, &c., during the whole of their existence, it may be separated by treating the tissue with alcohol, or hydrochloric or nitric acid, and then the interior vesicle appears shrivelled up and separated from the wall of the cavity. If this view be correct, the cells, as usually recognised, might be regarded as lacunæ in the inter-cellular substance, and the inclosed primordial utricles as the real cells. But the reality of the alleged primordial utricle has recently been called in question, and the supposed internal membrane is held to be merely the limiting surface of the cell-contents shrunk away from the inside of the containing cavity, and perhaps somewhat consolidated and defined by the re-agents employed. Still, whether the cell-contents have a vesicular limiting membrane or not, they originally present a marked contrast in chemical nature to the containing cell-wall and inter-cellular substance, and would appear to fulfil a different purpose in the process of tissue-development.†

Primordial Utricle of Mohl.

Besides such cells, phænogamous or flowering plants contain tubes, vessels, and other forms of tissue (fig. 2′,⁴ ⁶); but a great many plants of the class cryptogamia are composed entirely of cells, variously modified, it is true, to suit their several destinations, but fundamentally the same throughout: nay, there are certain very simple modes of vegetable existence, in which a single cell may constitute an entire plant, as in the well-known green powdery crust which coats over the trunks of trees, damp walls, and other moist surfaces. In this last case, a simple detached cell exercises the functions of an entire independent organism, imbibing and elaborating extraneous matter, extending

* Die vegetabilische Zelle; or English translation by Prof. Henfrey.

† See an interesting discussion of this subject by Mr. Huxley in the British and Foreign Medical Review for 1853.

itself by the process of growth, and continuing its species by generating other cells of the same kind. Even in the aggregated state in which the cells exist in vegetables of a higher order, each cell still, to a certain extent, exercises its functions as a distinct individual; but it is now subject to conditions arising from its connection with the other parts of the plant to which it belongs, and is made to act in harmony with the other cells with which it is associated, in ministering to the necessities of the greater organism of which they are joint members. These elementary parts are therefore not simply congregated into a mass, but combined to produce a regularly organised structure; just as men in an army are not gathered promiscuously, as in a mere crowd, but are regularly combined for a joint object, and made to work in concert for the attainment of it; living and acting as individuals, but subject to mutual and general control.

Transformation of vegetable cells. Now the varied forms of tissue found in the higher orders of plants do not exist in them from the beginning; they are derived from cells. The embryo plant, like the embryo animal, is in its early stages entirely formed of cells, and these of a very simple and uniform character; and it is by a transformation of some of these cells in the further progress of development that the other tissues, as well as the several varieties of cellular tissue itself, are produced. The principal modes, as far as yet known, in which vegetable cells are changed, are the following.

Enlargement. 1. The cells may increase in size; simply, or along with some of the other changes to be immediately described.

Change of figure. 2. They alter in shape. Cells have originally a spheroidal or rounded figure; and when in the progress of growth they increase equally, or nearly so, in every direction, and meet with no obstacle, they retain their rounded form. When they meet with other cells extending themselves in like manner, they acquire a polyhedral figure (fig. 2′, [1 2]) by mutual pressure of their sides. When the growth takes place more in one direction than in another, they become flattened, or they elongate and acquire a prismatic, fusiform, or tubular shape (fig. 2′, [3 4 5]). Sometimes, as in the common rush, they assume a starlike figure, sending out radiating branches, which meet the points of similar rays from adjacent cells (fig. 3′.)

Coalescence with each other. 3. The cells coalesce with adjoining cells, and open into them. In this way a series of elongated cells placed end to

end may open into one another by absorption of their cohering membranes, and give rise to a tubular vessel.

Fig. 2′.*

Alteration of substance, and contents.

4. Changes take place in the substance and in the contents of the cells. These changes may be chemical, as in the conversion of starch into gum, sugar, and jelly, and in the production of various coloured matters, essential oils, and the like. Or they may affect the form and arrangement of the contained substances; thus, the contents of the cell very frequently assume the form of granules, or spherules, of various sizes; at other times the contained matter, suffering at the same time a change in its chemical nature and in consistency, is deposited on the inner surface of the cell-wall, so as to thicken and strengthen it. Such "secondary deposits," as they are termed by botanists, usually occur in successive strata, and the deposition may go on till the cavity of the cell is nearly or completely filled up (fig. 4′). It is in this way that the woody fibre and other hard tissues of the plant are formed. It further appears that the particles of each layer are disposed in lines, running spirally round the cell. In place of forming a continuous layer, these secondary deposits may leave little

Fig. 3.′†

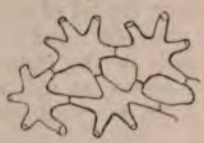


Fig. 4′.‡

* Textures seen in a longitudinal section of the leaf-stalk of a flowering plant.

† Stellate vegetable cells.

‡ Cross section of ligneous cells containing stratified deposit.

spots of the cell-wall uncovered, or less thickly covered, and thus give rise to what is named pitted tissue (fig. 2′,[6]); or they may assume the form of a slender fibre or band, single, double, or multiple, running in a spiral manner along the inside of the cavity, or forming a series of separate rings or hoops, as in spiral and annular vessels (fig. 2′,[7]). New matter may be absorbed or imbibed into the cells; or a portion of their altered and elaborated contents may escape as a secretion, either by transudation through the cell-wall, or by rupture or absorption of the membrane. Lastly, in certain circumstances, cells may be wholly or partially removed by absorption of their substance.

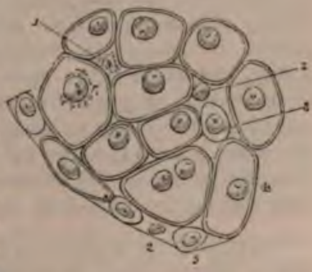
5. Cells may produce or generate new cells. The mode in which this takes place will be immediately considered, in speaking of the origin of animal cells. Production of new cells.

FORMATION OF THE ANIMAL TEXTURES.

Passing now to the development of the animal tissues, it may first be remarked generally, that in some instances the process exhibits an obvious analogy with that which takes place in vegetables; certain of the animal tissues, in their earlier conditions, appearing in form of a congeries of cells, almost entirely resembling the vegetable cells, and, in their subsequent transformations, passing through a series of changes in many respects parallel to some of those which occur in the progress of vegetable development. Cartilage affords a good example of this. Figures 5′ and 6′, A, are magnified representations of cartilage in its early condition; and whoever compares them with the appearance of vegetable cells, shown in figures 1′ and 2′, must at once be struck with the resemblance. Fig. 6′, B and C, shows the subsequent changes on the primary cells of cartilage; the parietes are seen to have become thickened by deposit of fresh

Resemblance of the process in animals and vegetables.

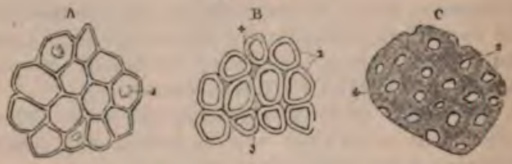
Fig. 5′.*



* Section of a branchial cartilage of a Tadpole, showing the early condition of the cells; magnified 450 diameters (Schwann).

material, the spaces within the cells are consequently diminished, while the mass between the cavities is increased. Now this change seen to occur in the cartilage cells, though there may be a question as to the precise mode in which it is brought about, may very fairly be compared with the thickening of the sides of the vegetable cells, which takes

Fig. 6′.*



place when they are converted into the woody and other hard tissues. Again, in most cartilages the cells increase in number as they diminish in size, new ones being formed within the old, as happens in many vegetable structures.†

The instance now given, and others to the same effect, which will be mentioned as we proceed, tend to show the fundamental resemblance of the process of textural development in the two kingdoms; but, when we come to inquire into the various modifications which that process exhibits in the formation of particular textures, we encounter serious difficulties. The phenomena are sometimes difficult to observe, and, when recognised, they are perhaps susceptible of more than one interpretation; hence have arisen conflicting statements of fact, and differences of opinion, at present irreconcileable, which future inquiry alone can rectify, and which in the mean time offer serious obstacles to an attempt at generalisation. In what follows, nothing more is intended than to bring together, under a few heads, the more general facts as yet made known respecting the formation of the animal textures, in so far as this may be done without too much anticipating details, which can only

* Cartilage of the branchial ray of a fish (*Cyprinus erythrophthalmus*) in different stages of advancement; magnified 450 diameters (Schwann).

† Remak and Leidy affirm that the corpuscle of cartilage corresponds with the primordial utricle of vegetable tissues; the chondrin-substance being homologous with the vegetable cell-wall and intercellular tissue. This view is adopted by Mr. Huxley, in the paper to which reference has already been made.

be suitably and intelligibly given in the special history of each texture.

Structure of Cells.—A cell, before it has undergone alteration, is a round or oval vesicle, formed of thin, transparent, homogeneous, flexible membrane; varying considerably in size, but never passing beyond the dimensions of a microscopic object. It contains in its interior a fluid or more consistent matter, pellucid or opaque, and in the latter case generally granular. In the greater number of cells there is also to be seen, at some period of their existence, a smaller body, called the "nucleus," which, as will afterwards appear, performs an important part in their economy. Schleiden attributed to it the function of producing the cell, and accordingly named it the "cytoblast," an appellation synonymous with "cell-germ." In the nucleus are commonly to be seen one or two, rarely more, minute eccentric spots; these are the nucleoli. Cells;—their structure.

The nucleus (fig. 1′, ¹) is of a round or oval shape, and more constant in size than the cell itself: its average diameter in animal cells is from $\frac{1}{5000}$th to $\frac{1}{4000}$th of an inch; its aspect is usually granular and dark, often with a yellowish hue, but sometimes quite homogeneous, transparent, and colourless. In some cases it appears to be solid throughout, being then made up of fine molecular matter, or consisting of a cluster of large granules: in other instances, especially in animal cells, its mass appears to be hollow, or at least less consistent in the centre; or it may present itself as a perfect vesicle, inclosing matters of very variable nature. It seems probable, also, that the large granules, of which some nuclei appear to be made up, are in reality vesicles, containing peculiar matters in their interior. Nucleus.

The nucleolus (fig. 1′, ²) is a round, sharply defined, generally dark, fat-like granule, probably vesicular at an early period. Of its real nature little is known; it has even been questioned whether the little spots termed nucleoli are actually corpuscles or vesicles inclosed in the nucleus, or merely minute cavities in its substance. Schleiden, however, states, that, in crushing the nucleus of vegetable cells, he has seen the nucleolus remain entire, and in such cases, of course, it must have been a distinct body. In many cells the nucleus presents no appearance of a nucleolus. Nucleolus.

The nucleus may sometimes perhaps lie free in the cavity of the cell; but more commonly it is attached to the inside of the cell-wall. Situation of nucleus.

Effect of chemical agents.

It very generally happens, that, when cells are exposed to the action of certain chemical agents, their different parts are differently acted on. Thus, in many cases, acetic acid speedily dissolves the granular or coloured contents of the cell, leaving the nucleus entire, and rendering it more sharply defined and more conspicuous; and the cell-membrane itself may be sometimes dissolved by the same agent, and the nucleus liberated. But, notwithstanding this and other aids to investigation, it is not always possible to say whether a given corpuscle is to be reckoned as a cell, or as a vesicular nucleus.

Cells are often seen without nuclei; in vegetable cellular tissues, indeed, this is the general rule: but, doubtless, in most of these instances nuclei have at one time been present, and have subsequently disappeared. Cells occur, however, both in animal and vegetable structures, in which nuclei have never at any time been discovered.

It is further to be observed that the animal cell is by some physiologists considered to be homologous, not with the vegetable cell commonly so called, but with the primordial utricle supposed to be contained within it.

Blastema.

Origin and Multiplication of Cells.—The soft or liquid organisable matter out of which cells are immediately produced, is named "blastema," or "cytoblastema." This substance may be contained in cells; it may be lodged in their interstices, or in the meshes of a tissue; or it may be deposited on the surface of parts. When the circulation of the blood is once established in the animal system, the clear part of that fluid, "the plasma," or "liquor sanguinis," as it is called, may be regarded as a generally diffused blastema, or at least as a general source whence the organisable material or blastema is derived. There is reason to believe that new cells may arise in any of those situations in which the blastema is found; that is to say, they may be formed within previously existing or parent cells, or in the interstitial and free blastema. The included or "endogenous" mode of origin is the universal, or at least the most general in the vegetable kingdom; it occurs also very commonly in the animal body, as in the ovum, in cartilage, and in some other structures. Schwann maintained that in animals the free or interstitial mode of origin was the more common, but this opinion has not been generally adopted by subsequent observers.

Formation of Cells.—As to the process by which cells

are formed, it appears, from the statements of competent observers, that it may take place in more ways than one; and it must be confessed that, for the present at least, these several modes of production of cells cannot with certainty be referred to one common principle.

Origin of nucleus.

As cells are formed in many instances around or upon previously existing nuclei, we have first to inquire how the nucleus itself originates; and here we meet with a difference of opinion. Schleiden and Schwann conceive that elementary granules first appear in the blastema; that then, round one or sometimes more of these, serving as nucleoli, fresh matter is aggregated, and the resulting little mass, becoming defined on the surface, constitutes the nucleus (fig. 7′,[1 2 3]). Schwann compares the process to that of crystallisation, and ascribes the chief differences between the two phenomena to the circumstance, that the permeable organic substance of the cell admits of increase, not only by external apposition of new particles, but by the intus-susception of new matter between the particles already deposited; whereas a crystal can grow only in the former way.* Henle suggests a different view as to the formation of the nucleus, and brings forward arguments to show that it is formed independently of a nucleolus. He supposes that elementary granules of a discoid figure and from $\frac{1}{12000}$th to $\frac{1}{6000}$th of an inch in diameter, first appear in the blastema; that two, three, or four of these group together to form a little clump; that their union is at first imperfect, and may continue so even some time after the cell is somewhat advanced in formation; but that they ultimately become completely blended into a single mass,—the nucleus. It is well known that in many cells, such as the corpuscles of lymph, mucus, and pus, the nucleus, when acted on by weak acetic acid, appears divided, either completely or partially, into two or three segments, and these Henle conceives to be its constituent granules, as yet imperfectly united.

Elementary granules.

Nevertheless, he does not deny that a nucleus may be formed by the aggregation of matter round a single elementary granule, and such a mode of formation differs from that proceeding from a nucleolus, as

* Whatever opinion may be entertained as to the soundness of this and other speculative views of Schwann respecting the economy of cells, there can be no question that his discussion of them is highly instructive; it will be found in his admirable exposition of the whole subject of the cellular origin of the animal tissues. (Microscopische Untersuchungen, &c. Berlin, 1839.)

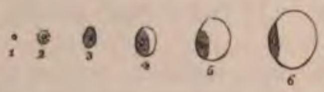
described by Schleiden, only in the interpretation of the phenomena, not in the facts observed. Indeed, it is not easy to see how, in any case, a distinction is to be made between the "elementary granules" of a nucleus, especially when they have not coalesced, and Schleiden's nucleoli. It is clear, also, that the nucleus contains, besides the granules, some other matter which surrounds them and binds them together, and which is softened or dissolved by acetic acid. Respecting these elementary granules, Henle further states, that "they present themselves wherever new formations are about to take place." He supposes that they are, for the most part, minute vesicles filled with fat, but that in forming a nucleus their chemical nature is changed, the nucleus acquiring the characters of a protein compound. Lastly, he thinks it probable that these vesicular bodies are originally merely minute particles of oil which acquire a vesicular envelope of albuminoid matter, on the physical principle pointed out by Ascherson, viz. that globules of oil when brought into contact with liquid albumen, or some similar substance with which oil does not mix, become instantly surrounded with a coherent film or coating of that substance, and thus acquire a vesicular character.

A nucleus, however it may have originated, may give rise to new nuclei by its subdivision.

Formation of a cell on a nucleus.

1. Formation of a cell on a nucleus.—Schwann regards the formation of a cell and the formation of a nucleus as a repetition of the same process; a deposit having taken place around the nucleolus to form the nucleus, the membrane of the cell is formed on the surface of the latter, at first closely surrounding it, but soon separating at one side, and gently rising up like a watch-glass on a watch (fig. 7′,[4]). The cell-wall, continuing to extend, soon becomes much larger than the nucleus, which at last is left at some point of the circumference of the cell imbedded in the substance of the membrane, where it may either remain, or be removed by liquefaction or absorption (fig. 7′, [5 6]). This is the process, as it has been traced in vegetables by Schleiden, who was the first to discover the important part performed by the nucleus, or "cytoblast," as he accordingly named it.

Fig. 7′.*



Schwann conceives that animal cells usually originate from nuclei or cytoblasts, in like manner. A layer of matter is deposited and condensed on the surface of the nucleus; it then rises in form of a film or membrane, and separates to a

* Plan representing the formation of a nucleus, and of a cell on the nucleus, according to Schleiden's view.

greater or less extent from the nucleus, which remains adherent to its inner surface, or assumes a more central position. The cell-membrane becomes firmer and usually thicker as it extends; its expansion being accompanied by actual growth and increase of substance, and not being simply the result of mechanical distension by the fluid which accumulates in its cavity.

Once the cell-wall is formed, the nucleus may remain without further change; or it may continue to grow larger, but always less rapidly than the envelope; or it may disappear altogether, as already stated: indeed this is the general rule with vegetable cells. Other changes which it undergoes will be afterwards mentioned.

2. The above process may be modified by the aggregation of granular or other matter round the nucleus before the formation of the cell-wall. An example of this is afforded in the formation of the ovum, in which the nucleus (*germinal vesicle*) becomes surrounded with a certain amount of granular yolk-substance before the inclosing cell-wall (*vitellary membrane*) appears. The formation of cells within the tubular glands of the stomach is adduced as another instance.

Both the above-described modes of formation, 1 and 2, may occur either free or within pre-existing cells. The latter case requires separate exposition, and is considered in the next following paragraphs.

3. Endogenous formation of cells round multiplied nuclei of a pre-existing cell.

Increase of cells by division of nucleus.

Division of Nucleus.—The most frequent mode of endogenous cell-formation is to be referred to this head. The first thing usually observed is a metamorphosis of the nucleus; it becomes elongated, acquires two nucleoli, and subsequently divides into two. The nuclei then divaricate, and a wall of separation arises, which divides the parent cell into two distinct spaces, each of which contains a single nucleus, and one half of the contents; or each nucleus with its share of the cell-contents becomes surrounded by a proper cell-wall.

Kölliker states that wherever clear observation can be obtained, a division and divarication of the nucleoli always precede the division of the nuclei. The formation of young, or daughter-cells may proceed to a considerable extent within the parent-cells: the latter either remain or they coalesce with the intercellular matrix, and cease to exist as histologically distinct structures.

Cells formed by cleaving of the yolk.

The curious phenomenon of furrowing, or rather cleaving, of the yolk, now known to occur in the ova of many animals as one of the earliest effects of fecundation, is connected with the production of cells round nuclei previously involved in granular cell-contents.

The following is an outline of that process, as observed by Kölliker in the ova of certain parasitic worms, in which it presents itself in its least complex form, and can be traced with comparative ease.

Before impregnation, there is seen, as usual, within the ovum in the midst of the yolk the vesicular body named the "germinal vesicle;" this contains a smaller mass within it, "the macula germinativa," and has therefore the aspect of a nucleolated nucleus. After the ovum has been fertilised, the germinal vesicle disappears, or becomes changed, and in its place there arises in the midst of the yolk, around a new nucleolus, a new nucleus, the primary nucleus of the embryo. (This has been termed the first "embryonic cell.") At the same time the mass of the yolk appears to shrink, as if its granules had become more densely congregated round the central nucleus. This first nucleus gives place to two others; then the yolk divides into two halves, and each half incloses one of the first pair of nuclei in its centre (fig. 8′, A). The first two nuclei are succeeded by twice as many new ones,

Fig. 8′.*

and the two masses of yolk are subdivided into four, each new yolk-segment inclosing a nucleus in its centre, as before (fig. 8′, B). The central nuclei and the inclosing segments of the yolk are again doubled so as to form eight, and this duplication of the nuclei and concomitant cleaving of the yolk are continued till the masses are greatly increased in number and reduced in size (C, D, E); each of them becoming

* Cleaving of the yolk after fecundation.—A, B, C, (from Kölliker,) ovum of Ascaris nigrovenosa; D and E, that of Ascaris acuminata (from Bagge).

at a certain stage of the process surrounded by membrane, and thus forming a cell, containing its nucleus, with more or less of the matter of the yolk in different instances. Their further changes and ultimate destination it is unnecessary here to pursue.

While it is admitted that the segments of the yolk eventually become inclosed by membranes and form true cells, it has been questioned whether its earlier and larger subdivisions are really surrounded by an enveloping membrane. Acknowledging the difficulty of the question, I should nevertheless be disposed, from what I have seen in the ovum of the ascaris, to answer it in the affirmative, as regards that instance at least. As to the mode of multiplication of the included nuclei, we can hardly doubt that each pair of young nuclei are formed within the nucleus immediately preceding, by subdivision of its nucleolus. The duplication of the nucleus probably takes place before the division of its including yolk-mass (see lowest segment of B), and is a necessary condition of it. As to the mechanism of the latter process, it has been presumed that the nuclei exercise a sort of attraction on the substance of the yolk, causing it to gather round them as so many separate centres. The shrinking of the granular mass, already noticed, apparently from the more close aggregation of its granules round the central cell, is in harmony with this supposition, but there are reasons for doubting its correctness. I may remark that in the ova of the ascaris nigrovenosa, and asc. acuminata, the granules of the yolk exhibit very lively molecular movements. On one occasion, when one of the large segments, into which the yolk is first cleft, divided itself into two portions while actually under inspection, I first observed a very obvious heaving motion among the granules throughout the whole mass; then ensued a constriction at the circumference, which, proceeding inwards, soon completed the division; but all this time the central cells were quite hidden by the enveloping granular matter.

The process above described, in some animals, affects only a part of the yolk; while in others, again, it has not been discovered.

4. A cell may arise without the previous formation of a nucleus. Schwann describes such cells as occurring within larger ones in the "chorda dorsalis" (a transitory cartilaginous structure) of the tadpole and fish. He states that they commence as small spherules, which either from the beginning are, or subsequently become, hollow, and expand into cells. Vogt maintains that they afterwards acquire nuclei, but his description is ambiguous. Other examples are given of a cell commencing as a small granule or spherule, and subsequently acquiring a nucleus. Origin independently of nuclei.

Another mode in which a cell is said to be formed without a nucleus, is by the agglomeration of granular matter into a considerable mass, which becomes surrounded by a membrane; there results a cell filled with granular contents, but without a proper nucleus. The large granulated

corpuscles which have been described as sometimes occurring in inflammatory exudations, and in various morbid growths, under the name of "compound inflammation globules," are said to be examples of this (Henle). The sporules of certain algæ are also described as being formed in the same way.

Fissiparous multiplication.

5. There is another mode in which cells are multiplied, viz. from the division of those previously existing, and which has accordingly been called *fissiparous.* A multiplication of cells by division has been observed in the blood-corpuscles of embryos by Remak, and Kölliker thinks that it takes place in the chyle corpuscles of adult mammalia. The following is Kölliker's account of the process: "we see in elongating cells the production of two nuclei from the originally simple nucleus, apparently by division; the cells then suffer constriction in the middle, and contract more and more around the nuclei as they recede from each other, and at last separate into two cells, each of which contains a nucleus."*

Original source of germinative matter.

Seeing the successive generations of cells which proceed from a single one in the ovum, and the propagation of cells in a similar manner which in many circumstances occurs at after-periods, physiologists have been naturally led to look to the germinal vesicle of the ovum for the original source to which all succeeding cell-germs in the economy might be traced back; and, as that vesicle is itself derived from the parent organism, they have conceived that a peculiar germinative matter, probably constituting the substance of the germinal spot, is handed down from parent to offspring, and, receiving an impulse by fecundation, begins in the ovum the series of assimilative and reproductive actions which is afterwards continued throughout life. Dr. Barry has given a formal theory of the origin and multiplication of cells, in which he represents the germinative matter as a peculiar pellucid substance, and proposes to call it "hyaline." He conceived that this substance is derived from the germinal spot of the ovum, and, after fecundation by the male, acquires remarkable properties, among others, that of increasing by the assimilation of new matter, and that of propagating itself by division; and he supposed that the globules into which it divides form so many germs of new cells: according to him, therefore, the cell-germ is a globule of hyaline. He was farther of opinion, that many cells which have but a transitory existence, are intended for no other purpose than to reproduce the hyaline; successive generations of them being sometimes employed in elaborating this substance.

Dr. Barry's theory.

Transformation of animal cells.

Transformation of Cells and Blastema.—In the conversion of cells into the several textures, there is, in different

* Manual of Histology, p. 28.

instances, a great difference not only in the nature and extent of the change which the cells undergo, but also in the condition which these bodies have attained when the process of change commences. In some cases they have already acquired a distinct cell-wall and cavity; but in others they never attain the condition of cells, strictly so called, and the process of transformation begins whilst they may be said to be but in a nascent state. Indeed, in the development of certain textures, as will afterwards be explained, the preliminary process of cell-formation, if in the circumstances we may properly use such a term, goes no farther than the production of nuclei, and the blastema surrounding or lying between the nuclei, which themselves undergo transformation, is at once converted into the elements of the tissue. The following are the principal modes in which cells or their elements are metamorphosed; it being understood that two or more of the processes, here to be mentioned, may occur in the same cell, and that the nucleus also undergoes changes which will subsequently be explained.

Enlargement, alteration of shape.

1. Increase in size, and change of figure.—A cell may increase equally, or nearly so, in all its dimensions, in which case it preserves its globular shape; but more commonly the growth is greater in certain dimensions, and then the figure becomes depressed and discoid, or elongated and oval, fusiform, or strap-shaped. When growing cells meet one another, they generally acquire an angular or polyhedral figure; and this may be combined with elongation into the prismatic, or flattening into the tabular form, as exemplified in the columnar and scaly varieties of epithelium. All these changes correspond with similar transformations already spoken of, which occur in vegetable cells. A more remarkable change of figure occurs in those instances

Fig. 9.*

* Pigment cells from the tail of the Tadpole, magnified about two hundred and twenty-five diameters (Schwann).

where a cell shoots out into branches at various points of its circumference, as happens with certain varieties of pigment cells (fig. 9′); and this, too, may be not unaptly compared to the ramified or radiating cells found in the rush and some other plants (fig. 3′).

Alteration of substance and contents.

2. Alteration of substance and of contents.—While the above described changes of figure are going on, the cell-wall usually acquires increased density and strength; and in a flattened cell, when much extended, the opposite sides cohere so as to obliterate its cavity. The substance of cells may also be changed in its chemical nature, as in the instance of the cuticle, where the cells, while deep-seated, and recently formed, are soluble in acetic acid, but, as they advance to the surface, lose this property and acquire a corneous character.

Consumption of contents.

Granular matter contained within cells may be dissolved and consumed whilst the cell extends itself, as happens in the bird's egg when granular cells join to form the early rudiments of the embryo.

New deposits.

On the other hand, new matters may appear, as fat and pigment within the adipose and pigmentous cells, and the peculiar constituents of certain secretions in the cells of secreting organs: in which last case the cells may eventually burst, and discharge their contents.

Cellulose metamorphosis, Corpora amylacea.

An important cell-metamorphosis, in regard both of structure and chemical relation, is that presented by the bodies termed "amyloid," or "corpora amylacea." These are to be found in the fibrous substance of the cerebrum and cerebellum, in the pineal body, the choroid plexus, pia mater, nerves of special sense, in cholesterine masses, &c., and are much more widely distributed than was at first supposed, although their nature is as yet but imperfectly understood.

Structure.

If one of these little grains is gently pressed, with the addition of water, or of liquor potassæ, spheroidal corpuscles project from it, and become detached. Each corpuscle appears made up of concentric laminæ, surrounding a nuclear point, which may be centric or eccentric; and besides the concentric markings there are radiating lines.

Chemical characters.

With regard to the chemical constitution of these bodies there is a difference of opinion; some observers maintain that they consist of phosphates and carbonates of lime, and of phosphate of ammonia and magnesia; with a nitrogenous organic basis, apparently albuminous: while others assert the presence of a substance which, with iodine and sulphuric acid, gives the reactions of cellulose.

It is questionable whether these bodies originate from a metamorphosis of cells, or of their nuclei, or whether, as Henle confidently affirms, they are derived from a modification of fat contained in granular cells.* Origin.

As in plants, too, the new substance may be so deposited as to augment the thickness and strength of the cell-wall, of which an example occurs in the thickening of the sides and narrowing of the cavity of cartilage-cells by layers of new matter on their internal surface. According to Henle, the deposit sometimes occurs on the outer surface of the cell-wall. Or the process may assume still more of a plastic and organizing character, as in the endogenous production of young cells, already described, and the formation of the spontaneously moving bodies named spermatozoa or spermatic animalcules, which, in plants, as well as in animals, are produced in the cavity of a cell. Thickening of cell-wall.

These plastic changes are equally unexplained with the other alterations of form and structure which accompany the production and metamorphoses of cells. As regards the changes in the quantity and chemical nature of the contained matter, it may be remarked, that the introduction of new matter into a cell is so far a phenomenon of imbibition, and, as such, must be to a certain extent dependent on the endosmotic effect produced by the substance already within the cell, and on the comparative facility with which the matter to be introduced is imbibed and transmitted by the permeable cell-wall. Some substances, moreover, being more readily imbibed than others of a different nature, the quality as well as the quantity of the imbibed material will be so far determined by the same circumstances. But, while an alteration in the contents of a cell may be thus brought about by the imbibition of one kind of matter in preference to another, the contained substance may be also changed in its qualities by a process of conversion taking place within the cell, and there are two conceivable ways in which this conversive or "metabolic" process may possibly occur. 1. Chemical action may be mutually exerted in the ordinary way between the matter originally contained in the cell and that subsequently introduced into it. 2. The process may be referred to the class of phenomena denominated by chemists "catalytic" actions, or actions by "contact," in which a chemical change is induced in a compound by the presence of another body, which, as far as appears, does not itself necessarily suffer alteration, and it is conceived that the cell-membrane or nucleus may exert this species of influence on the matters contiguous to it. Cause of these changes.

This seems also a fitting place to mention that the well-known tremulous movement which so frequently affects minute particles of matter, is not unfrequently observed in the molecular contents of cells, and depends simply upon physical conditions. But in many vegetable Movements within cells.

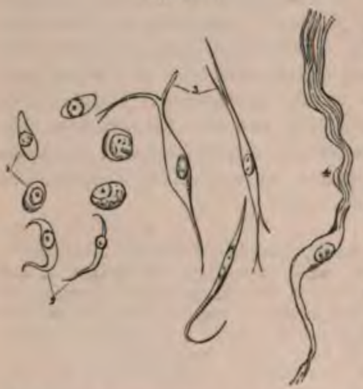
* See Henle in Canstatt's Jahresbericht, 1853, 1. Bd. p. 23, and a paper by Dr. Arlidge in Brit. and For. Med. Chir. Rev., 1854.

cells a motion of a different character, and affecting larger-sized corpuscles, is seen. These corpuscles move in a steady and regular manner along the inside of the cell-wall, and in a constant direction. This motion is named "rotation" by vegetable physiologists; the Chara and Vallisneria afford beautiful and well-known examples of it.*

Division into fibres.

3. Division into fibrils.—In the formation of certain tissues, cells which have increased in size and altered in shape, generally by elongation and flattening, appear to be resolved into fine fibres. Schwann supposed that the bundles of fibrils which constitute the chief part of the areolar tissue were formed by a process of this kind. He describes the cells as first extending themselves in two opposite directions, into an elongated and usually fusiform figure (fig. 10,′ 1, 2), then dividing at the extremities into fibrils (fig. 10,′ 3); the division at length reaching the middle part (fig. 10,′ 4), and extending through it, so as to convert the elongated cell into a bundle of parallel fibrils; the nucleus persisting for a time, but at last disappearing. There are reasons, however, for doubting the correctness of Schwann's view.

Fig. 10′.†



Henle ascribes the formation of areolar tissue to quite a different process, as will be afterwards explained. He admits the occurrence of spindle-shaped cells, split or ramified at their ends, both in healthy tissues and in diseased growths, but he thinks they do not give origin to the white fibres of areolar tissue. Though colourless, they seem allied to the system of ramified pigment cells.

4. Changes in the relation of cells to each other.

Insulated cells.

a. Cells may remain isolated, as in the instance of the

* It has recently been announced that cilia (which had been long sought for) have at length been discovered as the cause of this motion. See Journal of Microscopic Science.

† Cells becoming developed into areolar tissue, according to Schwann. Magnified four hundred and fifty diameters.

corpuscles of blood, chyle, and lymph, and those formed in certain secretions. The first-mentioned corpuscles float freely in fluid, which may be looked on as a sort of liquid blastema.

b. They may be united into a continuous tissue, by means of a sufficiently consistent intercellular substance; their parietes remaining distinct. The epithelium and the cuticle with its appendages, afford instances of this. Cohering cells.

c. The parietes of adjoining cells may be inseparably blended with each other, or with the intercellular substance. Cartilage is an example. Blending of parietes.

d. The parietes of adjacent cells coalesce at particular points, and absorption taking place, their cavities become united. It is supposed that ramified cells may thus open into one another, and Schwann conceives that the networks of capillary vessels originate in this way. In other instances the coalescing cells are placed in a longitudinal series, and by their union form a continuous tube, as happens in the vasiform tissues of vegetables. In certain cases, the tube formed by united cells becomes the receptacle of new and peculiar matter, which is deposited in it by an ulterior process of organization; thus, according to Schwann, in the formation of muscular and nervous tissue, a tube is first produced by the coalescence of a series of cells, and within this the muscular fibrillæ are formed in the one case, and the peculiar matter of the nervous fibre in the other. Union of cell cavities.

e. We may here also include the process by which Henle conceives what he calls a "complex fibre," or "complex fasciculus," to be formed. Cells placed in a row are supposed to coalesce into a sort of axis; round this axis fibres are laid on, which are themselves derived from elongated or otherwise altered cells; and outside of all is formed an inclosing sheath. He supposes that nervous fibres and the fibres (primitive fasciculi) of muscles are formed on this principle; the matter surrounding the axis being fluid in nerves, but in muscle arranged into fibrils. As to the mode in which the homogeneous inclosing tube is produced, he is uncertain. The axis of complex fasciculi may persist, or it may disappear. Complex fasciculi.

5. Formation of membranes and fibres from the blastema, without the intervention of actual cells.—As already mentioned, there are certain cases in which there is reason to suppose that the blastema, in place of forming distinct cells, which thereupon become blended, at once gives rise to con- Membranes and fibres formed without actual cells.

tinuous membranes or fibres. In such cases nuclei are present in the blastema, and subsequently disappear, or undergo metamorphosis; but how far their presence determines the transformation of the surrounding substance, we have no means of deciding.

a. The blastema may in this manner form a simple homogeneous film, from which the nuclei for the most part disappear. The capsule of the lens and the brittle layer on the posterior part of the cornea, are instances of such simple glass-like membranes, and probably arise in the way mentioned.

b. In the formation of the areolar, fibrous, and some other tissues, according to Henle's view of that process, the blastema is first converted into long flattened bands, which lie between parallel rows of nuclei. Each of these bands, which are not more than $\frac{1}{4000}$th of an inch broad, is then subdivided into a bundle of fine, parallel fibrils, which soon acquire the waved aspect characteristic of the microscopic filamentous bundles of the areolar and fibrous tissues. While this goes on, the nuclei undergo remarkable changes, to be immediately noticed.

Changes of nuclei.

6. Changes in the nuclei of cells.—The nucleus may grow somewhat larger as the cell increases in magnitude, at least at first; thus it enlarges and flattens in epithelium cells. It may then remain without farther change, or it may disappear: it is persistent in most varieties of epithelium, but in the flattened cells of the cuticle and nails it disappears. In other cases, the substance of the nucleus may undergo a chemical change.

Nucleus persistent or evanescent;

proliferous;

We have already spoken of proliferous nuclei, which undergo subdivision and give rise to young cells.

metamorphic.

In many tissues composed of fibres, as the areolar, the fibrous, the substance of the cornea, and the muscular tissue, the nuclei become lengthened and attenuated, and often crescentic, crooked, or serpentine; in which state they may be seen lying between the fibres of the tissue, on applying acetic acid, in which they are insoluble. Having reached this condition, they may then disappear, being first broken up into rows of little dots. But many of them have been thought, instead of vanishing, to extend themselves at both ends into a fibre, which meets and joins with similar prolongations from neighbouring nuclei; the little bodies themselves getting gradually thinned down, so that, in some cases, all trace of them in the thread is lost. In this

manner a second set of fibres are produced, which have been named "nuclear fibres." These fibres lie between the other fibres, or bundles of fibrils, of the tissue in which they occur; sometimes parallel with them, sometimes winding round them, sometimes alternating with them in layers. They are remarkable for their dark, well-defined outline, and, like the nuclei themselves, are insoluble in acetic acid; so that, by means of that re-agent, they may be rendered conspicuous amidst the other elements of the tissue with which they are mixed. But it will be afterwards seen that they strongly resemble, or rather are identical with the fibres of yellow elastic tissue; and, in fact, it would appear that, like the elastic fibres, the so-called nuclear-fibres really originate, not from mere nuclei, but from the elongation, ramification, and union of true cells. So-called nuclear fibres.

7. Ulterior changes in the blastema.—Intercellular substance.—The blastema is usually in great part consumed in the progress of development, but a small portion remains between the cells or other elements of the tissues, generally increasing in consistency, and serving to cement them together; it then constitutes the intercellular or intermediate substance. This substance varies in its condition and aspect: it is represented as being soft and granular in the areolar tissue; in cartilage it is at first pellucid and hyaline, but often undergoes a change, and becomes fibrous; in certain forms of ossifying cartilage it is hardened and calcified by deposition of earthy salts. In cartilage, moreover, the substance interposed between the cell-cavities increases in quantity as development advances; but, as in this case there is also a thickening of the cell-walls, which are blended with the intervening substance, it is impossible to say how far the increase in question is due to true intercellular deposit. Intercellular substance.

NUTRITION AND REGENERATION OF THE TEXTURES.

Nutrition.—The tissues and organs of the animal body, when once employed in the exercise of their functions, are subject to continual loss of material, which is restored by nutrition. This waste or consumption of matter, with which, so to speak, the use of a part is attended, takes place in different modes and degrees in different structures. In the cuticular textures the old substance simply wears away, or is thrown off at the surface, whilst fresh material is added from below. In muscular texture, on the other hand, the Nutrition, what?

process is a chemical or chemico-vital one; the functional action of muscle is attended with an expenditure of moving force, and a portion of matter is consumed, whether directly or indirectly, in the production of that force; that is, it undergoes a chemical change, and being by this alteration rendered unfit to serve again, is removed by absorption. The amount of matter changed in a given time, or, in other words, the rapidity of the nutritive process, is much greater in those instances where there is a production and expenditure of force, than where the tissue serves merely passive mechanical purposes. Hence, the bones, tendons, and ligaments are much less wasted in exhausting diseases than the muscles, or than the fat, which is consumed in respiration, and generates heat. Up to a certain period, the addition of new matter exceeds the amount of waste, and the whole body, as well as its several parts, augments in size and weight: this is "growth." When maturity is attained, the supply of material merely balances the consumption; and, after this, no steady increase takes place, although the quantity of some matters in the body, especially the fat, is subject to considerable fluctuation at all periods of life.

Growth.

It would be foreign to our purpose to enter on the subject of nutrition in general; we may, however, briefly consider the mode in which the renovation of substance is conceived to be carried on in the tissues.

Nutritive material, whence derived.

The material of nutrition is immediately derived from the plasma of the blood, or liquor sanguinis, which is conveyed by the blood-vessels, and transudes through the coats of their capillary branches; and it is in all cases a necessary condition that this matter should be brought within reach of the spot where nutrition goes on, although, as will immediately be explained, it is not essential for this purpose that the vessels should actually pass into the tissue.

Differences in the mode of nutrition: superficial;

In cuticle and epithelium, the nutritive change is effected by a continuance of the process to which these textures owe their origin. The tissues in question being devoid of vessels, nutrient matter, or blastema, is furnished by the vessels of the true skin, or subjacent vascular membrane; cells arise in the blastema, enlarge, alter in figure, often also in chemical nature, and, after serving for a time as part of the tissue, are thrown off at its free surface.

interstitial.

But it cannot in all cases be so clearly shown that nutrition takes place by a continual formation and decay of the

structural elements of the tissue; and it must not be forgotten, that there is another conceivable mode in which the renovation of matter might be brought about, namely, by a molecular change which renews the substance, particle by particle, without affecting the form or structure. Still, although conclusive evidence is wanting on the point, it seems probable that something more than a mere molecular change generally takes place, but of what precise nature, is, as yet, only matter of conjecture. Some have supposed that the nuclei seen among the fibres of many tissues may probably minister to their nutrition, and it has been conceived that these nuclei may serve as centres of assimilation and increase, inducing a deposition and organisation of matter in their neighbourhood, and propagating themselves by spontaneous division.

Office of the vessels.

In the instance of cuticle and epithelium, no vessels enter the tissue, but the nutrient fluid which the vessels afford, penetrates a certain way into the growing mass, and the cells continue to assimilate this fluid, and pass through their changes at a distance from, and independently of, the blood-vessels. Whether, in such cases, the whole of the residuary blastema remains as intercellular substance, or whether a part is again absorbed into the vessels, is not known. In other non-vascular tissues, such as articular cartilage, the nutrient fluid is doubtless, in like manner, conveyed by imbibition through their mass, where it is then attracted and assimilated. The mode of nutrition of these and other non-vascular masses of tissue may be compared, indeed, to that which takes place throughout the entire organism in cellular plants, as well as in polypes and some other simple kinds of animals, in which no vessels have been detected. But even in the vascular tissues the case is not absolutely different; in these, it is true, the vessels traverse the tissue, but they do not penetrate into its structural elements. Thus the capillary vessels of muscle pass between and around its fibres, but they do not enter them; still less do they penetrate the fibrillæ within the fibre; these, indeed, are much smaller than the finest vessel. The nutrient fluid, on exuding from the vessels, has here, therefore, as well as in the non-vascular tissues, to permeate the adjoining mass by transudation, in order to reach these elements, and yield new substance at every point where renovation is going on. The vessels of a tissue have, indeed, been not unaptly compared to the artificial channels of irrigation

faintly granular ; it surrounds the nucleus, and occupies the space between it and the vesicular envelope. The envelope and red matter are obviously of a soft and yielding nature, for the corpuscles alter their shape on the slightest pressure, as is beautifully seen while they move within the vessels; they are also elastic, for they readily recover their original form again. It must be remarked that the blood corpuscles when viewed singly appear very faintly coloured, and it is only when collected in considerable quantity that they produce a strong deep red.

Difference in man and mammalia.

A structure consisting of envelope, nucleus, and red matter, as shown in the large blood-disks of amphibia, may be demonstrated in many other instances, and by analogy has been inferred to exist in all, man not excepted. But although in the early stages of their formation the blood corpuscles of man and mammalia may consist of an envelope and nucleus, it seems to be satisfactorily established that in their perfect or final condition they are destitute of nuclei; and accordingly we find that some observers, while they deny the general existence of a nucleus in the human blood corpuscles, believe it is present in a few of them.

Alteration by exposure.

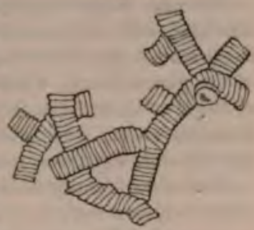
The human blood corpuscles, as well as those of the lower animals, often present deviations from the natural shape, which are most probably due to causes acting after the blood has been drawn from the vessels, but in some instances depend upon abnormal conditions previously existing in the blood. Thus, it is not unusual for many of them to appear indented or jagged at the margin, when exposed under the microscope (fig. 11′, [3]), and the number of corpuscles so altered often appears to increase during the time of observation. This is, perhaps, the most common change ; but they may become distorted in various other ways, and corrugated on the surface ; not unfrequently one of their concave sides is bent out, and they acquire a cup-like figure. It is even a question with some observers, whether the biconcave figure which the corpuscles generally present may not be due to a distension of the circumferential part of an originally flat disk. Mr. Gulliver made the curious discovery, that the corpuscles of the Mexican deer and some allied species present very singular forms, probably in consequence of exposure ; the figures they assume are various, but most of them become lengthened and pointed at the ends, and then often slightly bent, not unlike caraway-seeds.

The red disks, when blood is drawn from the vessels, sink

in the plasma; they have a singular tendency to run together, and to cohere by their broad surfaces, so as to form by their aggregation cylindrical columns, like piles or rouleaus of money, and the rolls or piles themselves join together into an irregular network (fig. 13′). In a few moments after this has taken place, a heaving or slowly oscillating motion is observable in the mass, and the rolls may then become broken up, and the corpuscles more or less completely disjoined (Jones). Generally the corpuscles separate on a slight impulse, and they may then unite again. The nature of the attraction exerted between the corpuscles is doubtful; but it may be remarked, that the phenomenon will take place in blood that has stood for some hours after it has been drawn, and also when the globules are immersed in serum in place of liquor sanguinis.

Aggregation into rolls.

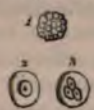
Fig. 13′.*



Pale or colourless Corpuscles (fig. 14′).—These are comparatively few in number, of a rounded and slightly flattened figure, rather larger in man and mammalia than the red disks, and varying much less than the latter in size and aspect in different animals. In man (during health) the proportion of the white corpuscles to the red is said to be as 1 to 50. In oviparous vertebrata as 1 to 15, or even more; but the numbers cannot be assigned with certainty. Henle gives the proportion 1 to 80; Donders and Moleschott 1 to 373. They are destitute of colour, finely granulated on the surface, and specifically lighter than the red corpuscles. The large corpuscles are less distinctly granular than the small. Water has little effect on them; acetic acid brings speedily into view a nucleus, which frequently presents a reddish tint (Virchow and Kölliker), consisting sometimes of one, but more commonly of two, three, or four, large clear granules (fig. 14′, [2, 3]). The number of apparent nuclei is

Pale corpuscles.

Fig. 14′.†



* Red corpuscles collected into rolls (after Henle).

† Pale corpuscles of human blood, magnified about five hundred diameters. 1. Natural aspect. 2 and 3. Acted on by weak acetic acid, which brings into view the single or composite nucleus.

said by Mr. Wharton Jones to depend upon the strength of the acetic acid employed; if the acid is much diluted, only one is seen; if strong acid is used, the nucleus breaks up into three or four nuclear-looking particles; a delicate envelope at the same time comes into view, which becomes distended so as to augment the size of the globule, and is eventually dissolved, the nucleus remaining.

Changes in shape.

The pale corpuscles frequently present the appearance of bursting, with the escape of their granular contents. This is shown by Mr. W. Jones to be an incorrect interpretation of the phenomenon, which consists, in reality, of the bulging of these cells, and the formation of processes, into which the granules enter, but from which they subsequently recede, the cell-wall regaining its original form.

Granules.

Granules of a fatty nature occur in varying numbers; sometimes very scantily, or not at all, sometimes in vast numbers so as to give the serum a turbid, milky appearance. These are probably derived directly from the chyle (its "molecular base"), and they are especially seen in the blood of Herbivora, in sucking animals, and in pregnant women.

Occasional elements.

Besides the foregoing, the blood occasionally presents the following constituents:—(1) cells, enclosing blood-corpuscles, noticed by Ecker and Kölliker in the blood of the spleen and hepatic vessels, and elsewhere. (2) Pigmentous and colourless granule-cells. (3) Pale, fine-granular, roundish aggregations, in the splenic blood. (4) Peculiar bodies, three or four times larger than the pale corpuscles, but in other respects resembling them. (5) Caudate, pale or pigmentous cells. (6) Fibrinous coagula. (7) Crystals. These latter, which have been termed hæmatin crystals, have been sometimes observed within the corpuscles, especially in fishes; they may be readily obtained from drawn blood by allowing a drop to dry for a short time on a slip of glass, and then adding a drop of water. They have the form of needles, columns, or plates; and are of pale, or red colour. According to Reichert, Schmidt, and others, they consist of albuminous matter coloured by hæmatin. They have been seen in splenic blood without the addition of water.

Plasma, its properties.

Liquor Sanguinis, or Plasma.—This is the pale clear fluid in which the corpuscles are naturally immersed. Its great character is its strong tendency to coagulate when the blood is withdrawn from the circulating current, and on this account it is difficult to procure it free from the

corpuscles. Nevertheless, by filtering the slowly coagulable blood of the frog, as was first practised by Müller, the large corpuscles are retained by the filter, while the liquor sanguinis comes through in perfectly clear and colourless drops, which, while yet clinging to the funnel, or after they have fallen into the recipient, separate into a pellucid glassy film of fibrin, and an equally transparent diffluent serum. When human blood is drawn in inflammatory diseases, as well as in some other conditions of the system, the red particles separate from the liquor sanguinis before coagulation, and leave the upper part of the liquid clear. In this case, however, the plasma is still mixed with the pale corpuscles, which, being light, accumulate at the top. On coagulation taking place in these circumstances, the upper part of the clot remains free from redness, and forms the well-known "buffy coat" so apt to appear in inflammatory blood. Now, in such cases, a portion of the clear liquor may be taken up with a spoon, and allowed to separate by coagulation into its fibrin and serum, so as to demonstrate its nature. Dr. A. Buchanan has pointed out another method of separating the liquor sanguinis from the red corpuscles, which I have repeatedly tried with success; it consists in mixing fresh-drawn blood with six or eight times its bulk of serum, and filtering through blotting paper; the admixture of serum delays coagulation, and a great part of the liquor sanguinis, of course diluted, passes through the filter, and subsequently coagulates. How separated.

Microscopic characters.

Coagulated plasma, whether obtained from buffy blood, or exuded on inflamed surfaces, presents, under the microscope, a multitude of fine filaments confusedly interwoven, as in a piece of felt; but these are more or less obscured by the intermixture of corpuscles and fine granules, the former having all the characters of the pale corpuscles of the blood. The filaments are no doubt formed by the fibrin, as it solidifies in the coagulation of the liquor sanguinis.

Blood may be freed from fibrin by stirring it with a bundle of twigs, which entangle the fibrin as it concretes.

COAGULATION OF THE BLOOD.

Phenomena of coagulation.

In explaining the constitution of the plasma, we have been obliged so far to anticipate the account of the coagulation of the blood. The following are the phenomena which usher in and which accompany this remarkable change.

Immediately after it is drawn, the blood emits a sort of exhalation, the "halitus," having a faint smell; in about three or four minutes a film appears on the surface, quickly spreading from the circumference to the middle; a minute or two later the part of the blood in contact with the inside of the vessel becomes solid, then speedily the whole mass; so that, in about eight or nine minutes after being drawn, the blood is completely gelatinised. At about fifteen or twenty minutes, or it may be much later, the jelly-like mass begins to shrink away from the sides of the vessel, and the serum to exude from it. The clot continues to contract, and the serum to escape for several hours, the quickness and extent of the process varying exceedingly in different cases; and, if the serum be poured off, more will usually continue to drain slowly from the clot for two or three days.

Nature of change.

The nature of the change which takes place in the coagulation of the blood has been already spoken of; it is essentially owing to the coagulation of the liquor sanguinis, the fibrin of that liquid separating in form of a solid mass, which involves the corpuscles but allows the serum to escape from it in greater or less quantity. But although the solidification of the fibrin and formation of a red clot, would undoubtedly take place independently of any co-operation on the part of the corpuscles, still it must not be forgotten that, in point of fact, the red disks are not altogether passive while coagulation goes on; for they run together into rolls, as already described, and the circumstance of their doing so with greater or with less promptitude materially affects the result of the coagulating process. Thus there

Buffy coat.

seems good reason to believe that, as H. Nasse has pointed out, one of the causes; and in inflammatory blood probably the chief cause, of the production of the buffy coat, is an exaltation of the natural tendency of the red disks to run together, whereby being more promptly and more closely aggregated into compact masses, they more speedily subside through the liquid plasma, leaving the upper part of it colourless by the time coagulation sets in; and Mr. Jones has drawn attention to another influential circumstance derived from the same source, namely, the more rapid and close contraction of the network, or spongework as he terms it, into which the little rolls of corpuscles unite, and the consequent expulsion of great part of the liquor sanguinis from its meshes before the fibrin solidifies, the mass of

aggregated corpuscles naturally tending to the lower part of the vessel, whilst the expressed plasma being lighter, accumulates at the top. Of course, it is not meant to deny that more tardy coagulation of the blood would produce the same result as more speedy aggregation of the corpuscles; it is well known, indeed, that blood may be made to show the buffy coat by delaying its coagulation, but buffed inflammatory blood is not always slow in coagulating.

Various causes accelerate, retard, or entirely prevent the coagulation of the blood; of these it will here suffice to indicate the more important and best ascertained. **Circumstances affecting coagulation.**

1. Temperature.—Cold delays, and at or below 40 degrees Fahr. prevents, coagulation; but even frozen blood, when thawed and heated again, will coagulate. Moderate elevation of temperature above that of the body promotes coagulation. **Temperature.**

2. Coagulation is accelerated by free exposure of the blood, even *in vacuo*, but especially by exposure to air and various other gases; also, but in a less degree, by contact with foreign bodies generally. On the other hand, the maintenance of its fluidity is favoured by exclusion of air, and by contact with the natural tissues of the body, so long at least as these retain their usual vital and physical properties. **Exposure.**

3. Cessation of the blood's motion *within the body* favours coagulation, probably by arresting those perpetual changes of material, both destructive and renovative, to which it is naturally subject in its rapid course through the system. Agitation of *exposed* blood, even *in vacuo*, accelerates coagulation, most probably by increasing its exposure. **Motion or rest.**

4. Water, in a proportion not exceeding twice the bulk of the blood, hastens coagulation; a larger quantity retards it. Blood also coagulates more speedily when the serum is of low specific gravity, indicative of much water in proportion to the saline ingredients. **Addition of water.**

5. Almost every substance that has been tried, except caustic potash and soda, when added to the blood *in minute proportion*, hastens its coagulation; although many of the same substances, when mixed with it in somewhat larger quantity, have an opposite effect. The salts of the alkalies and earths, added in the proportion of two or three per cent. and upwards, retard, and, when above a certain quantity, suspend or prevent coagulation; but, though the process be thus suspended, it speedily ensues on diluting the mixture **Salts and other substances.**

with water. The caustic alkalies permanently destroy the coagulability of the blood. Acids delay or prevent coagulation. Opium, belladonna, and many other medicinal agents from the vegetable kingdom, are said to have a similar effect; but the statements of experimenters by no means entirely agree respecting them.

Condition of the system.

6. Certain states of the system.—Faintness occasioned by loss of blood favours coagulation; states of excitement are said to have, though not invariably, the opposite effect. Impeded aëration of the blood in disease, or in suffocative modes of death, makes it slow to coagulate. So also in cold-blooded animals, with slow circulation and low respiration, the blood coagulates less rapidly than in the warm-blooded; and, among the latter, the tendency of the blood to coagulate is strongest in birds, which have the greatest amount of respiration, and highest temperature.

Differs in arterial and venous.

In the sexes.

7. Coagulation commences earlier, and is sooner completed, in arterial, than in venous blood. Dr. Nasse finds that woman's blood begins to coagulate nearly two minutes sooner than that of the male sex.

Proportion of clot and serum.

In general, when blood coagulates quickly, the clot is more bulky and less firm, and the serum is less effectually expressed from it; so that causes which affect the rapidity of coagulation will also occasion differences in the proportion of the moist clot to the exuded serum.

There is no sufficient evidence of evolution of heat or of disengagement of carbonic acid from blood during its coagulation, which some have supposed to occur.

CHEMICAL COMPOSITION OF THE BLOOD.

The blood is slightly alkaline; it has been found that a drachm of blood is capable of saturating rather more than a drop of vinegar. Carbonic acid, oxygen and nitrogen gases, may be extracted from it in proportions which differ in arterial and venous blood, and which will be subsequently given. On being evaporated, 1000 parts of blood yield, on an average, about 790 of water, and 210 of solid residue.

It has been ascertained by analysis that blood has the same ultimate composition as flesh; an observation which is obviously of great interest in reference to the office performed by the blood in nutrition. A comparative examination of dried ox-blood and dried flesh (beef), by Playfair and Bœckmann, gave the following mean result:

Salts.—1. Having soda and potash as bases, combined with lactic, carbonic, phosphoric, sulphuric, and fatty acids. Also chlorides of sodium and potassium, the former in large proportion. Schmidt has pointed out that the potash salts exist almost exclusively in the blood corpuscles and the soda salts principally in the serum. In the corpuscles there are chloride of potassium and phosphate of potass: in the serum, chloride of sodium, and phosphate of soda. The following table (giving the mean of eight experiments) exhibits the relative quantities of potassium and sodium, and of phosphoric acid and chlorine, in the blood corpuscles and plasma. Salts.

100 parts of Inorganic Matters.

Blood-Corpuscles.		*Plasma.*		*Blood-Corpuscles.*		*Plasma.*	
K.	Na.	K.	Na.	PO.	Cl.	PO.	Cl.
40·89	9·71	5·19	37·74	17·64	21·00	6·08	40·68

The Table also shows that the chlorides are, relatively to the phosphates, in much larger quantity in the plasma than in the blood-cells; and that the phosphates are, relatively to the chlorides, in much larger proportion in the blood-cells than in the plasma.

2. Lactate of ammonia. 3. Salts with earthy bases, viz. lime and magnesia with phosphoric, carbonic, and sulphuric acids.

The earthy salts are for the most part associated with the albumen, but partly with the crassamentum. As they are obtained by calcination, it has been suspected that the phosphoric and sulphuric acids may be in part formed by oxidation of the phosphorus and sulphur of the protein compounds. Nasse found in 1000 parts of blood 4 to 7 of alkaline, and 0·53 of earthy salts.

Gaseous contents.—In a well-exhausted receiver of an air-pump, blood yields carbonic acid, and, according to Magnus, also oxygen and nitrogen gases. Carbonic acid may also be extracted from it by exposing it for some time to a stream of hydrogen. Chemists, however, are by no means all satisfied that the gas obtained by any of these methods exists in the blood in a free state. Gases.

Liebig brings arguments to prove that the carbonic acid extricated *in vacuo* is derived from bicarbonate of soda; a solution of which, it is well known, yields up a portion of its carbonic acid when atmospheric pressure is removed from it. It is also worthy of remark that hydrogen extracts more carbonic acid when the blood has stood for some time than when it is perfectly recent; from which it is suspected that the

gen 5·37, nitrogen 10·40, oxygen 11·75, and iron 6·64; or C_{44}, H_{22}, N_3, O_6, Fe.

Iron of the blood.

Chemists have differed in opinion as to the condition in which iron exists in hæmatin: some have supposed that the metal enters into the formation of the organic compound, and holds the same rank in its constitution as the carbon, hydrogen, and other constituents; but others conceive that it is in the state of oxide or salt, and as such, combined or mixed with the organic matter, in a similar manner, perhaps, as oxides and salts may be combined with albumen. An experiment of Scherer seems conclusive against the former view, and shows that the iron, though a constant ingredient in the red corpuscle, is not an essential constituent of the hæmatin. By treating cruor with sulphuric acid, the chemist named succeeded in entirely separating the iron from it, and after this it nevertheless imparted an intensely red colour to alcohol. This fact also proves that the red colour of the blood is not due to iron, as some have believed.

Globulin.

Globulin.—When the hæmatin has been extracted from the blood-corpuscles by the foregoing method, the globulin remains in combination with sulphuric acid. This is a substance which agrees with albumen in composition, and in all its properties, except the two following, viz. its insolubility in serum, that is, in a saline solution which holds albumen dissolved; and, secondly, its coagulation, by heat, in form of a granular mass, different in aspect from coagulated albumen. Henle suggests that both peculiarities may be due to the circumstance that the albuminous matter is enclosed, and in some degree protected by the envelopes of the corpuscles, which remain after extraction of the hæmatin; and he thinks that globulin is probably nothing but albumen with the membranous envelopes (and nuclei, when present,) of the blood particles. Lecanu and Liebig consider it albumen.

Cruor.

The *cruor*, or matter of the red corpuscles, which consists of the globulin and hæmatin together (hæmato-globulin), may be dissolved in water; and its solution, which contains the envelopes in suspension, coagulates by a heat of 181 degrees. Its effects with re-agents, both in its soluble and coagulated state, resemble those of albumen under like circumstances. Berzelius reckons the relative proportions of globulin and hæmatin as 94·5 of the former, and 5·5 of the latter. Schmidt makes them 87·59, and 12·41 respectively. The corpuscles are supposed also to contain a solid phosphuretted fat in small quantity, but its proportion has not been determined. 100 parts of dry cruor yield by calcination about 1·3 of brown alkaline ashes which consist

of carbonate of soda with traces of phosphate 0·3, phosphate of lime 0·1, lime 0·2, subphosphate of iron 0·1, peroxide of iron 0·5, carbonic acid and loss 0·1.

The red corpuscles form by far the largest part of the organic matter in the blood: their proportion may be ascertained by filtering defibrinated blood mixed with solution of Glauber's salt, as already mentioned; or by weighing the dried clot, and making allowance for the fibrin it contains. The latter method, however, will serve only to give a rough estimate, as the very variable amount of serum remaining in the clot and affecting its weight cannot be determined. Lecanu reckons the amount of the *dry* corpuscles as about 120 or 130 parts in 1000 of blood. Schmidt from three classes of calculations, which it is needless here to repeat, arrived at the conclusion that the proportion of *moist* red corpuscles in 1000 parts of blood, is from 480 to 520; and this represents the blood corpuscles as containing three-fourths of their weight of water.* Proportion of red corpuscles.

Denis and Lecanu state that, as a general rule the proportion of red particles is greater in the blood of the male sex than in that of the female, whilst the proportion of albumen in the serum is about the same in both. Lecanu gives the following mean result, derived from numerous analyses, exhibiting the proportion of crassamentum and water in the blood of the two sexes. No deduction is made for the fibrin; but, considering its small relative quantity, any possible variation in it cannot materially affect the general conclusion. Differences in amount of crassamentum.

	Male.	*Female.*
Crassamentum, from	115·8 to 148	68·3 to 129·9
Water	778 to 805	790 to 853

He found the following differences in the crassamentum according to temperament:

	Male.	*Female.*
Sanguine temperament	136·4	126·1
Lymphatic temperament	116·6	117·3

As regards age, Denis found the proportion of crassamentum greatest between the ages of 30 and 40. Sudden loss of blood rapidly diminishes it. In two women who had suffered from uterine hæmorrhage, the crassamentum amounted to only 70 parts in 1000. The same effect may be observed to follow ordinary venesection. In a person bled three times in one day, Lecanu found in the first drawn blood 139, and in the last only 76 parts of crassamentum in the 1000. This effect may be produced very suddenly after a bleeding. Prevost and Dumas bled a cat from the jugular vein, and found 116 parts of crassamentum in 1000, but in blood drawn five minutes afterwards, it was reduced to

* For an account of Schmidt's method see Lehmann's Physiological Chemistry (Cavendish Society's Translation), vol. ii. p. 162.

bloods is in their colour. Venous blood is rendered bright red by exposure to atmospheric air, or to oxygen. This effect is greatly promoted by the saline matter of the serum, and may be accelerated by adding salts or sugar to the blood, especially by carbonate of soda and by nitre; but the presence of serum, or of saline matter, is not indispensable to its production, for although the clot, when washed free from serum, does not redden on exposure to oxygen, yet it is found that the fresh clot, or red matter of the blood, when deprived of serum, and dissolved or diffused in water, still becomes perceptibly brighter and more transparent on exposure to oxygen, though the effect is slow in appearing, whilst the colour is deepened, and the solution acquires a turbid aspect, on being agitated with carbonic acid. Salts added to dark blood, without exposure to air or oxygen, cause it to assume a red colour, which, however, does not equal in brightness the arterial red. Exposure to carbonic acid darkens arterial blood. The immediate cause of the change of colour is uncertain; it has, with most probability, been ascribed to a change in the state of aggregation of the colouring matter, and in the figure of the corpuscles.

Blood of the portal vein.

Portal blood.—The blood of the portal vein is said to contain proportionally less fibrin and albumen than other blood, more fat, and fewer red corpuscles, though these are said to contain proportionally more hæmatin. Lehmann found sugar in the portal blood of a horse, but only in about twelve times less quantity than in the blood of the hepatic veins.

THE LYMPH AND CHYLE.

Lymphatic and lacteal system.

Vessels.

A transparent and nearly colourless fluid, named "lymph," is conveyed into the blood, by a set of vessels distinct from those of the sanguiferous system. These vessels, which are named "lymphatics," from the nature of their contents, and "absorbents" on account of their reputed office, take their rise in nearly all parts of the body, and, after a longer or shorter course, discharge themselves into the great veins of the neck; the greater number of them previously joining into a main trunk, named the thoracic duct,—a long narrow vessel which rises up in front of the vertebræ, and opens into the veins on the left side of the neck, at the angle of union of the subclavian and internal

jugular; whilst the remaining lymphatics terminate in the corresponding veins of the right side. The absorbents of the small intestine carry an opaque white liquid, named "chyle," which they absorb from the food as it passes along the alimentary canal; and, on account of the milky aspect of their contents, they have been called the "lacteal vessels." But in thus distinguishing these vessels by name, it must be remembered, that they differ from the rest of the absorbents only in the nature of the matters which they convey; and that this difference holds good only while digestion is going on; for at other times the lacteals contain a clear fluid, not to be distinguished from lymph. The lacteals enter the commencement of the thoracic duct, and the chyle, mingling with the lymph derived from the lower part of the body, is conveyed along that canal into the blood.

Both lacteals and lymphatics, in proceeding to their destination, pass through certain small, solid, and vascular bodies, named lymphatic glands, in which they are in some degree modified in structure and arrangement, as will be afterwards described: so that both the chyle and lymph are sent through these glands before being mixed with the blood. Glands.

This much having been explained to render intelligible what follows, we may now consider the lymph and the chyle, which, as will be seen, are intimately related to the blood.

LYMPH.

The lymph may be procured free from admixture of chyle, and in quantity sufficient for examination, from the larger lymphatic vessels of the horse or ass. It may also be obtained by opening the thoracic duct of an animal that has fasted for some time before being killed. It is a thin fluid, transparent and colourless, or occasionally of a pale yellow hue; its taste is saline, its smell faint and scarcely perceptible, and its reaction alkaline. Sometimes the lymph has a decided red tint, of greater or less depth, which becomes brighter on exposure to the air. This redness is due to the presence of coloured corpuscles, like those of the blood: and it has been supposed, that such corpuscles exist naturally in the lymph, in greater or less quantity; but according to Mr. Lane,* they are introduced into the

Lymph.

Physical properties.

Cause of its occasional red colour.

* Cyclopædia of Anatomy, art. Lymphatic System.

lymphatic vessels accidentally; he adduces an experiment to show, that when an incision is made into a part, the blood will very readily enter the lymphatics which are laid open, and pass along into larger trunks; and he conceives that in this way blood is conveyed into the thoracic duct, or any other large vessel, exposed as usual by incision immediately after the animal is killed.

Microscopic examination. The lymph, when examined with the microscope, is seen to consist of a clear liquid, with corpuscles floating in it. Lymph corpuscles. These "lymph corpuscles," or lymph globules, agree entirely in their characters with the pale corpuscles of the blood, which have been already described (page xli.). Occasionally, smaller particles are found in the lymph; also, but more rarely, a few oil globules of various sizes, as well as red blood-corpuscles, the presence of which has just been referred to.

Plasma. The liquid part (lymph-plasma) bears a strong resemblance in its physical and chemical constitution to the plasma of the blood: and, accordingly, lymph fresh-drawn from the vessels coagulates after a few minutes' exposure, and Coagulum. separates after a time into clot and serum. This change is owing to the solidification of the fibrin contained in the lymph-plasma, and in this process most of the corpuscles are Serum. entangled in the coagulum. The serum, like the corresponding part of the blood, consists of water, albumen, extractive matters, fatty matters in very sparing quantity, and salts.

Human lymph has been obtained fresh from the living body in two instances, in which a lymphatic vessel had been accidentally opened by a wound. It has been found to agree in all material points with the lymph of quadrupeds. Its specific gravity, in the case examined by Marchand and Colberg, was 1037.

Result of analysis of lymph. The following analyses exhibit the proportions of the different ingredients; but it must be explained, that the amount of the corpuscles cannot be separately given, the greater part of them being included in the clot and reckoned as fibrin.

Lymph of the ass from the lymphatics of the posterior limb (by Dr. G. O. Rees *):—

Water	96·536
Albuminous matter	1·200

* Medical Gazette, Jan. 1, 1841.

Fibrinous matter	0·120
Extractive matter soluble in water and alcohol	0·240
Extractive matter soluble in water only	1·319
Fatty matter	a trace.
Salts, viz.—Alkaline chloride, sulphate, and carbonate, with traces of alkaline phosphate, oxide of iron	0·585
	100·

Lymph from the lumbar lymphatics of the horse (Gmelin) :—

Water	96·10
Dried clot (fibrin, with corpuscles)	0·25
Dried serum, 3·65, viz.	
Albumen	2·76
Extractive matter soluble in alcohol (osmazome), with alkaline chloride, and acetate	0·69
Extractive matter soluble in water only, with alkaline carbonate, phosphate, and chloride	0·20
	100·

Human lymph from a lymphatic vessel on the instep of the foot (Marchand and Colberg) :—

Water	96·926
Fibrin	0·520
Albumen	0·434
Osmazome (and loss)	0·312
Fatty matters	0·264
Salts, viz.—Chlorides of sodium and potassium, alkaline carbonate, and lactate; sulphate and phosphate of lime, and oxide of iron	1·544
	100·

The proportion of fibrin has been supposed to increase as the lymph approaches the thoracic duct; thus, from the lumbar lymphatics of a fasting horse, Gmelin obtained 0·25 per cent. of dry coagulum, and from that of the thoracic duct of the same animal, 0·42 per cent. As regards the amount of albumen, Leuret and Lassaigne assign it at 5·7 per cent., but this includes the extractive matter; on the other hand, Berzelius suspects, that the method followed by Marchand and Colberg leads to too low an estimate; but there seems reason to think that, apart from all error, the proportion of this ingredient will be found to vary.

CHYLE.

The chyle of man and mammiferous animals is an opaque, white fluid, like milk, with a faint odour and saltish taste, slightly alkaline or altogether neutral in its reaction. It has often a decided red tint, especially when taken from the thoracic duct. This colour, which is heightened by exposure to air, is doubtless often due to the presence of blood

Chyle, its properties.

corpuscles, and may be then explained in the same way as the occasional red colour of lymph; but there is reason to believe that a red tint in the chyle is sometimes occasioned by the development of colouring matter in its own corpuscles, and independently of any admixture from without.

Constitution.

Like blood and lymph, both of which fluids it greatly resembles in constitution, the chyle consists of a liquid holding small particles in suspension. These particles are,

Chyle corpuscles.

1. *Chyle corpuscles*, or chyle globules, precisely like the lymph globules and pale blood corpuscles already described.

Fatty molecules.

2. *Molecules*, of extremely minute but remarkably uniform size, probably between $\frac{1}{36000}$ and $\frac{1}{24000}$ of an inch in diameter. These abound in the fluid, and form an opaque white molecular matter diffused in it, which Mr. Gulliver has named the *molecular base* of the chyle. The addition of ether instantly dissolves this matter, and renders the chyle nearly, but not quite, transparent; whence it may be inferred that the molecules are minute particles of fatty matter, and probably the chief cause of the opacity and whiteness of the chyle. They exhibit the usual tremulous movements common to the molecules of many other substances.

Oil globules.

3. *Oil globules;* these are of various sizes, but much larger than the molecules above described, and are often found in the chyle in considerable numbers.

Spherules.

4. *Minute spherules* (Gulliver), from $\frac{1}{24000}$ to $\frac{1}{8000}$ of an inch in diameter; probably of an albuminous nature, and distinguished from the fatty molecules by their varying magnitude and their insolubility in ether.

Free nuclei.

5. *Free nuclei* are found, according to Kölliker, in large numbers in the commencement of the lacteal vessels, &c., in smaller numbers in the efferent vessels of the glands. They are from $\frac{1}{10000}$ to $\frac{1}{3000}$ of an inch in diameter, and by endosmotic distension with water appear vesicular.

Plasma.

The plasma, or liquid part of the chyle, contains fibrin, so that the chyle coagulates on being drawn from the vessels, and nearly all the chyle corpuscles, with part of the molecular

Serum.

base, are involved in the clot. The serum which remains, resembles in composition the serum of lymph; the most notable difference between them being the larger proportion of fatty matter contained in the former.

Subjoined is an analysis, by Dr. Rees, of chyle taken from the lacteals of an ass after the fluid had passed the mesenteric glands, but before it entered the thoracic duct.

Water	90·237
Albuminous matter	3·516
Fibrinous matter	0·370
Extractive matter soluble in water and alcohol	0·332
Extractive matter soluble in water only	1·233
Fatty matter	3·601
Alkaline chloride, sulphate and carbonate, with traces of phosphate, oxide of iron	0·711
	100·

The chyle, when taken from the lacteal vessels before they have reached the glands, is generally found to coagulate less firmly than in a more advanced stage of its progress. In like manner the lymph, before passing the lymphatic glands, occasionally exhibits the same weak coagulation; but Mr. Lane justly remarks, that the lymph does not differ in coagulability in the different stages of its progress so decidedly and so generally as has been sometimes alleged; and this observation accords with the statement of Mr. Hewson on the same point.*

Fluid of human thoracic duct.

Dr. Rees has examined the fluid contained in the thoracic duct of the human subject. It was obtained from the body of a criminal an hour and a half after execution, and, from the small quantity of food taken for some hours before death, it must have consisted principally of lymph. It had a milky hue with a slight tinge of buff; part of it coagulated feebly on cooling: its specific gravity was 1024. Its analysis, compared with that of the chyle of the ass, shows less water, more albumen, less aqueous extractive, and a great deal less fat.† The following table, slightly modified, is extracted by Dr. Carpenter ‡ from the General Anatomy of Gerber, and presents in a concise form the relative proportions of the principal ingredients in the chyle in different parts of the absorbent system.

In the afferent or peripheral lacteals (from the intestines to the mesenteric glands)	Fat, in maximum quantity. Albumen, medium. Corpuscles, few or none, but free nuclei numerous. Fibrin, little or none.
In the efferent or central lacteals (from the mesenteric glands to the thoracic duct)	Fat, medium. Albumen, maximum. Corpuscles, numerous, but imperfectly developed; free nuclei, few. Fibrin, medium quantity.
In the thoracic duct	Fat, in minimum quantity. Albumen, medium. Corpuscles, numerous and distinctly cellular; free nuclei absent. Fibrin in maximum quantity.

* Experimental Inquiries, part ii. p. 105.
† Phil. Trans., 1842.
‡ Principles of Human Physiology, 4th ed., p. 458.

FORMATION OF THE CORPUSCLES OF THE LYMPH AND CHYLE.

Development of lymph corpuscles.

Very little is known concerning this process. No absorbent or open orifices having been discovered in the lymphatics, it can scarcely be supposed that the lymph globules are introduced into the vessels ready formed, unless it be imagined that the commencing lymphatics are destitute of membranous parietes, an opinion lately advanced by Brücke in regard to the lacteals, but of which there is scarcely sufficient evidence. The corpuscles are, therefore, most probably developed as cells within the lymphatic vessels, and there are various modes in which such a production of cells might be conceived to take place. Thus, according to one view, the lymph globules or cells are developed from nuclei in the liquid part of the lymph, which serves as a blastema. In this case the nuclei may be formed by aggregation of matter round nucleoli, which again may be derived as germs from other cells; or, as Henle is disposed to think, two or more fat particles may unite to form a nucleus in the way already described (page xix.). Upon another view it may be conceived that the lymph corpuscles are formed on the inner surface of the walls of their containing vessels, as epithelium or mucous corpuscles are produced on their supporting membrane; and that this process may be connected with the absorption of lymph into the vessels, in like manner as secretion into a gland-duct, or other receptacle, is accompanied by the formation and detachment of cells, as will be afterwards explained.

Formation of chyle globules.

The chyle globules, possessing the same characters as those of the lymph, are most probably formed in the same way; and their increase as the chyle advances whilst the free nuclei decrease, favours the opinion that nuclei are first produced, and give rise to the corpuscles.

FORMATION OF THE BLOOD CORPUSCLES.

In embryo of frog.

In the early embryo of the frog, (in which, perhaps, the steps of the process are best ascertained,) at the time when the circulation of the blood commences, the corpuscles of that fluid appear as rounded cells, filled with granular matter, and of larger average size than the future blood corpuscles. The cells in question have an envelope so delicate, that it is rather inferred to exist from the regular limitation of their outline than actually seen. They contain, concealed in the midst of the granular mass, a pellucid globular vesicle, which usually presents one or two small clear specks, situated eccentrically. The granular contents consist partly of fine molecules, exhibiting the usual molecular movements; and partly of little angular plates, or tablets, of a solid substance, probably of a fatty nature. After a few days, most of the cells have assumed an oval figure, and are somewhat reduced in size; the envelope has become more consistent, and can now be readily distinguished; and the granular matter is greatly diminished in quantity, so that the vesicular nucleus is conspicuous. Now, also, the blood corpuscles, previously colourless, have acquired a yellowish or faintly red colour. In a further stage, the already oval cell is flattened,

* Gulliver's Supplement to Gerber's Anatomy, p. 92.

the granules entirely disappear, the colour is more decided, and, in short, the blood corpuscle acquires its permanent characters. From this description it will be seen that the blood-cells which first appear, agree in nature with the cleavage cells, (described at page xxii.), and their production is probably connected with the process of segmentation, which is known to take place in the frog's ovum. The different parts of the embryo in its early condition, the heart, for example, are for a time entirely composed of cells of the same kind, and all have probably a common origin.

In egg of bird.

In the egg of the bird, the first appearance of blood corpuscles, as well as of blood-vessels, is seen in the blastoderma, or germinal membrane, a structure formed by the extension of the cicatricula in the early stages of incubation. The commencing embryo, with its simple tubular heart, is seen in the centre of this circular membrane, and blood-vessels appear over a great part of its area. These first vessels therefore, though connected with the heart, and intended to convey nutriment to the embryo, are formed in an exterior structure; but in a somewhat later stage, blood-vessels are developed in various textures and organs within the body. The formation of blood corpuscles in the vascular area of the blastoderma has been sedulously investigated by various inquirers: and from their concurrent statements we learn, that these corpuscles, at a certain stage of their progress, are rounded cells, larger than the blood-disks of the adult. They contain a granular nucleus, and are quite devoid of colour. These spheroidal colourless vesicles in their further advancement become flattened, but at first with a circular outline, and at length assume an oval figure. While undergoing these changes of form, they acquire a red colour, which is at first faint and yellowish, but gradually deepens; their envelope, too, becomes thicker and stronger.

As to the earlier part of the process,—the production of the above-mentioned round cells, whose subsequent conversion into coloured oval disks has just been described,—the statements of observers differ so widely, that no consistent account can be founded on them. It has been held that the cells which form the substance of the blastoderma and embryo partly pass directly into blood-cells, and partly generate the latter by endogenous multiplication. Again, it is affirmed that some blood-cells are formed from free nuclei floating in the intercellular fluid; and Remak maintains that they increase by subdivision. Hence, perhaps, it may be inferred that the end is attained in more ways than one.

In embryo of mammalia.

In the embryo of mammiferous animals, the corpuscles which first circulate in the blood-vessels are round, nucleated, colourless cells. In this condition they were observed by Wagner,* in very young embryos of rabbits, bats, and sheep; and Bischoff,† who confirmed the observation as regards the rabbit's embryo, remarks, that the primary blood-cells do not differ in appearance from the common primary cells, of which all the solid parts of the embryo are at first composed. This last-mentioned observation is important, and entirely agrees with what has been seen in the frog's ovum. The primary blood-cells are much larger than the future corpuscles—for the most part double their size;—they acquire a reddish colour, and are gradually converted into,

* Nachtraege zur vergleichenden Physiologie des Blutes, p. 36.
† Entwickelungsgeschichte des Kanincheneyes, p. 135.

or, at least, are succeeded by, smaller disk-shaped corpuscles without nuclei, possessing all the characters of the blood-disks of the adult. The mode in which the change or substitution is effected has not been traced.

Changes throughout life.

Throughout life the mass of blood is subject to continual change; a portion of it is constantly expended, and its place taken by a fresh supply. It is certain that the corpuscles are not exempted from this general change, but it is not known in what manner they are consumed, nor by what process new ones are continually formed to supply the place of the old. With regard to the latter question, it may be stated, that the explanation which has hitherto found most favour with physiologists, is, that the corpuscles of the chyle and lymph passing into the sanguiferous system, become the pale corpuscles of the blood; and that these last are converted into red disks. At the same time it is not improbable, that pale corpuscles may be also generated in the blood-vessels, independently of those derived from the chyle and lymph. As to the manner in which the pale corpuscles are transformed into the red, there is considerable difference of opinion. According to one view (adopted by Paget, Kölliker, and others), the pale corpuscles gradually become flattened, acquire coloured contents, lose their nuclei, and shrink somewhat in size, and thus acquire the characters of the red disks. But Mr. Wharton Jones has,* from an extended series of observations, arrived at the conclusion that, whilst in birds, reptiles, and fishes, the pale or lymph corpuscle, suffering merely some alteration of form and contents, becomes the red disk, its nucleus alone is developed into the red disk of mammalian blood. According to this view the red corpuscle of oviparous vertebrata is the transformed pale corpuscle, its development not proceeding beyond this stage; but the non-nucleated red disk of man and mammalia is not the homologue of the oval nucleated red disk of the oviparous vertebrata, but that of its nucleus. It is not within the scope of this work to enter upon a discussion of the relative merits of these opinions, and the reader is referred to Physiological works, and especially to Kölliker's Mikroskopische Anatomie, for a consideration of these and other views adopted by various authors upon the point at issue.†

EPIDERMIC, EPITHELIAL, OR CUTICULAR TISSUE.

Epithelium in general.

It is well known, that when the skin is blistered, a thin and nearly transparent membrane, named the cuticle or epidermis, is raised from its surface. In like manner, a transparent film may be raised from the lining membrane of the mouth, similar in nature to the epidermis, although it has in this situation received the name of "epithelium;" and under the latter appellation, a coating of the same kind exists on nearly all free surfaces of the body. It is true

* Philosophical Transactions, 1846.

† In the Sydenham Society's Translation of Kölliker's "Manual," there are interesting notes upon the formation of the blood corpuscles, by Mr. Busk and Mr. Huxley, who adopt the views of Mr. W. Jones.

that in many situations the epithelium cannot be actually raised from the subjacent surface as a coherent membrane, still its existence as a continuous coating can be demonstrated; and, although in different parts it presents other important differences, it has in all cases the same fundamental structure, and its several varieties are connected by certain common characters.

Where found.

The existence of a cuticular covering in one form or other, has been demonstrated in the following situations: viz. 1. On the surface of the skin. 2. On mucous membranes; a class of membranes to be afterwards described, which line those internal cavities and passages of the body that open exteriorly, viz. the alimentary canal, the lachrymal, nasal, tympanic, respiratory, urinary, and genital passages; as well as the various glandular recesses and ducts of glands, which open into these passages or upon the surface of the skin. 3. On the inner or free surface of serous membranes, which line the walls of closed cavities in the head, chest, abdomen, and other parts. 4. On the membranes termed synovial within the joints. 5. On the inner surface of the blood-vessels and lymphatics.

Structure and constitution.

This tissue has neither vessels nor nerves, and it is wholly devoid of sensibility; it, nevertheless, possesses a decidedly organised structure. Wherever it may exist, it is formed essentially of nucleated cells united together by a more or less cohesive intercellular matter. The cells, in whatever way they may be produced, make their appearance first in the deepest part of the structure, in a soft blastema deposited by the blood-vessels of the subjacent tissue; then, usually undergoing considerable changes in size, figure, and consistency, they gradually rise to the surface, where, in most cases, and perhaps in all, they are thrown off and succeeded by others from beneath. In many situations the cells form several layers, in which they may be seen in different stages of their progress, from their first appearance to their final desquamation. The layer or layers thus formed, take the shape of the surface to which they are applied, following accurately all its eminences, depressions and inequalities.

Its cells.

Cells differ in different parts.

In accordance with the varied purposes which the epithelium is destined to fulfil, the cells of which it is composed come to differ in different situations, in their figure, their size, their position in respect of each other, their degree of mutual cohesion, and in the nature of the matter they contain,

as well as in the vital endowments which they manifest; and, founded on these modifications of its constituent cells, four principal varieties of epithelium have been recognised, namely, the *scaly*, the *columnar*, the *spheroidal*, and the *ciliated*, each of which will now be described in particular.

Varieties.

Characters of the cell-nuclei.

It may first be remarked, however, that amidst these changes the nucleus of the cell undergoes little alteration, and its characters are accordingly remarkably uniform throughout. It is round or oval, and more or less flattened; its diameter measures from $\frac{1}{6000}$th to $\frac{1}{4000}$th of an inch, or more. Its substance is insoluble in acetic acid, and colourless, or has a pale reddish tint. It usually contains one or two nucleoli, distinguished by their strong, dark outline; and a variable number of more faintly-marked granules irregularly scattered. For the most part, the nucleus is persistent, but in some cases it disappears from the cell.

Scaly epithelium.

The *scaly*, *lamellar*, *tabular*, or *flattened* epithelium (pavement, or tesselated epithelium of the German anatomists). In this variety the epithelium particles have the form of small angular tables, or thin scales; in some situations forming a single thin layer, in others accumulating in many super-imposed strata, so as to afford to the parts they cover a defensive coating of considerable strength and thickness.

In a single layer.

As a *simple layer*, it is found on the serous, and some synovial membranes, the inner surface of the heart, blood-vessels and absorbents; also lining the cerebral ventricles and covering the choroid plexuses, on certain parts within the eye and ear, and in some gland ducts.

Fig. 15′.*

On serous membranes.

If the surface of the peritoneum, pleura, pericardium, or other serous membrane be gently scraped with the edge of a knife, a small quantity of soft matter will be brought away, which, when examined with the microscope, will be found to contain little shred-like fragments of epithelium, in which a greater or less number of its constituent

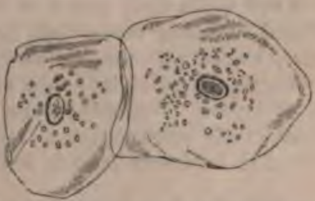
* Fragment of epithelium from a serous membrane (peritoneum), magnified 410 diameters. *a*, cell; *b*, nucleus *c*, nucleoli. (Henle.)

particles still hold together, like the pieces composing a mosaic work (fig. 15'). These particles, which are flattened cells, have for the most part a polygonal figure, and are united to each other by their edges. Each has a nucleus, apparently in or near the centre, but most probably attached to the cell wall. The addition of weak acetic acid renders the angular outline of the cells as well as the nucleus more distinct. The cells differ somewhat in size on different parts of the serous membrane, and those which cover the plexus choroides are found with processes projecting in various directions, and perfectly transparent.

The epithelium of the vascular system resembles in many parts that of the serous membranes; but in some situations the flattened cells, together with their nuclei, assume an oblong figure, and sometimes their outline becomes indistinct from blending of neighbouring cells. In the vascular system.

A scaly epithelium, in which the cells form several layers, (thence named "stratified") covers the skin, where it constitutes the scarf-skin, or epidermis, which, together with the hairs and nails, will be afterwards more fully described. In this form it exists, also, on the conjunctival covering of the eyeball; on the membrane of the nose for a short distance inwardly; on the tongue and the inside of the mouth, throat and gullet; on the vulva and vagina, extending some way into the cervix of the uterus; also (in both sexes), on a very small extent of the membrane of the urethra, adjoining the external orifice. It is found, also, on the synovial membranes which line the joints. Its principal use, no doubt, is to afford a protective covering to these surfaces, which are almost all more or less exposed to friction. Forming several layers; *stratified epithelium.*

Fig. 16'.*

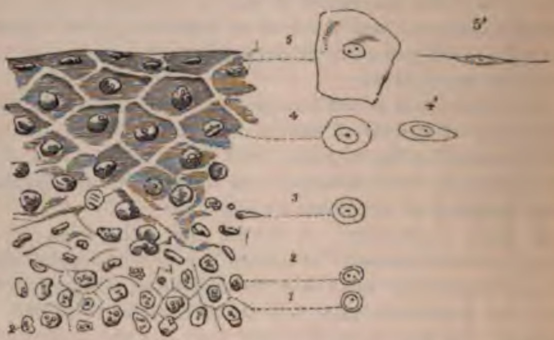


The cells in this sort of epithelium become converted into broad thin scales from $\frac{1}{850}$ to $\frac{1}{300}$ of an inch in diameter, which are loosened and cast off at the free surface. Such scales, both single and connected in little patches, may be at all times seen with the microscope in mucus scraped from the inside of the

* Epithelium scales from the inside of the mouth, magnified 260 diameters. (Henle.)

mouth, as shown in fig. 16′; but to trace the progressive changes of the cells, they must be successively examined at different depths from the surface, and the epithelium must also be viewed in profile, or in a perpendicular section, as exhibited in fig. 17′. In this manner, at

Fig. 17′.*



the deep or attached surface, small cells may be seen in the midst of a soft granular, or clear substance (blastema). These appear to be recently formed, for their cell-membrane closely invests the nucleus; nay it is alleged by good observers, that mere nuclei are also present, which subsequently acquire an envelope. Others, such as Kölliker, deny the existence of free nuclei in this situation, and ascribe the new cells wholly to endogenous multiplication. A little higher up in the mass the cells are enlarged; they have a globular figure, and are filled with soft matter; they next become flattened, but still retain their round or oval outline; then the continued flattening causes their opposite sides to meet and cohere, except where separated by the nucleus, and they are at length converted into thin scales, which form the uppermost layers. While they are undergoing this change of figure, their substance becomes more firm and solid, and their chemical nature is more or less altered; for the cell-mem-

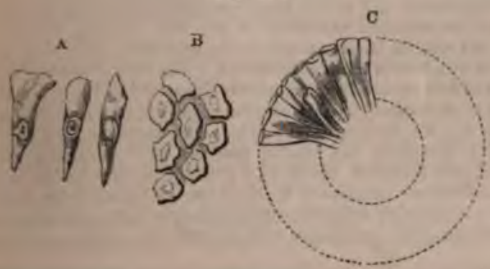
* Epithelium from the conjunctiva of the calf, folded so that the free surface forms the upper border of the figure, and rendered transparent by acetic acid. 1, 2, 3, 4, 5, progressive flattening of the cells as they rise to the surface. The outline figures represent single cells from different depths, viewed on their surface; and at 4′ and 5′, edgeways. Magnified 410 diameters. (Chiefly after Henle.)

brane of the softer and more deep-seated cells may be dissolved by acetic acid, which is not the case with those nearer the surface. The nucleus at first enlarges, as well as the cell, but in a much less degree; and it soon becomes stationary in its growth, having usually acquired an oval figure, and an eccentric position. The scales near the surface overlap a little at their edges, and their figure is very various; somewhat deeper it is mostly polygonal, and more uniform. Besides the nuclei, they often exhibit fat-globules and small scattered granules, like dots, and, according to Henle, are sometimes marked over with fine parallel lines.

In various parts, the more superficial and denser layers of the scaly epithelium can be readily separated from the deeper, more recently formed, and softer part which lies underneath; and this has led to the error of describing the latter as a distinct membrane, under the name of *rete mucosum*; this point will be again noticed in treating of the skin. Rete mucosum explained.

Columnar Epithelium.—In this variety (figs. 18′ and 19′), the constituent cells are elongated in a direction per- Columnar epithelium.

Fig. 18′.*



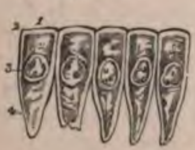
pendicular to the surface of the membrane, so as to form short upright columns, smaller or even pointed at their lower or attached extremity, and broader at the upper. They are mostly flattened on their sides, by which they are in mutual apposition, at least in their upper and broader part, and have, therefore, so far a prismatic figure, their broad flat ends appearing at the surface of the epithelium, in form of little polygonal areas (fig. 18′, B). The nucleus,

* A, columns of epithelium from the intestine magnified. B, viewed by their broad free extremity. C, seen in a transverse section of an intestinal villus. (From Henle.)

usually oval, and containing a nucleolus, is placed near the middle of the column, and is often so large in proportion to the cell, as to cause a bulging at that part; in which case, Mr. Bowman * observes, the height of the nucleus differs in contiguous columns, the better to allow of mutual adaptation. The particles from the epithelium of the gall-bladder are mostly without nuclei (Henle). Besides the nucleus, the columnar cell usually contains a certain amount of an obscurely granular matter; this may be distributed throughout the whole of the particle, or confined to its middle and lower end, the upper part of the column remaining transparent; or lastly, the granular matter may be surrounded on all sides by a transparent border, which some have supposed to be the wall of the cell. The appearance of these columnar epithelium cells, which are taken from the intestinal mucous membrane, varies according to the activity of the digestive process at the time.

Gruby, and more recently, Bruecke, have stated that the cells are open at their free surface, but this is denied by Kölliker and Bruch: Donders, however, maintains that as the cells grow, their nuclei push forwards towards the surface, and eventually escape (becoming the so-called mucus-corpuscles), and at this stage a second nucleus may be seen, low down, at the attached extremity of the cell. During digestion fat globules are seen in large numbers in the epithelium cells of carnivora, in smaller numbers in those of herbivora. The wall of the cell forming the basis or free surface is comparatively thick, and Kölliker has pointed out that it is marked by fine parallel striæ running perpendicular to the surface. He is disposed to think that these may in reality be caused by extremely fine tubular passages perforating the cell-wall in the assigned direction, which may possibly account for the entrance of oily molecules. Whatever be their import the striæ are distinctly visible; perhaps they indicate merely a finely columnar structure, such as that which exists on a larger scale in articular cartilage and enamel.

Fig. 19′.†



The little columns are held together, though sometimes very feebly, by intercellular substance, which fills up the wider space between their narrow ends, and even extends beyond their large extremities and forms a continuous layer over them on the free surface of the epithelium.

Shedding and renewal.

The columnar epithelium is unquestionably subject to

* Cyclopædia of Anatomy, art. Mucous Membrane.

† Columns of epithelium from the rabbit's intestine. 1. Free surface. 2. Broad outer end. 3. Nucleus. 4. Small inner extremity turned towards the mucous membrane magnified 308 diameters. (Henle.)

shedding and renovation, but the precise mode in which this takes place has not been ascertained.

Valentin infers, from his observations, that in most parts there are young cells in successive stages of advancement lying underneath the columnar particles and preparing to take their place, as occurs in the cuticle and other corresponding forms of the scaly epithelium. But in some situations, the little columns appear to rest immediately on the subjacent membrane, without any appearance of an intervening layer. It has also been supposed that the columnar epithelium cells are formed from the coalescence of two spheroidal cells. The occasional presence of two nuclei favours this view; but Gerlach, who has recently studied this subject, states that the presence of two nuclei is but a rare exception to the general rule; and further, that transitional forms between the spheroidal and columnar cells are frequently observed. Perhaps the epithelial coating may not undergo a slow and continual shedding and renewal, but may from time to time be cast off entirely and at once, in which case, the subjacent surface may remain denuded for a short time until its covering is restored, or a new epithelium may be formed preparatory to the shedding of the old, and ready to succeed it. Some have supposed, that a temporary denudation takes place in certain situations and circumstances; it has been stated for instance, that the epithelium is thrown off from the inner surface of the intestines during digestion, in order to enable the subjacent membrane to exercise its special function, and that, when this is accomplished, the epithelial covering is speedily reproduced. The separation of the epithelium in these cases is, however, certainly accidental.

The columnar variety of epithelium is confined to mucous membranes. Where found. It is found in the stomach; on the mucous membrane of the intestines in its whole extent; in the whole length of the urethra, except a small part at the orifice. It extends along the ducts of the greater number of glands, whether large or small, which open on the mucous membrane, but not through their entire length; for, at their extremities, these ducts have an epithelium of a different character. The inner membrane of the gall bladder is covered with columnar epithelium.

Spheroidal Epithelium.—In this variety, the cells for the Spheroidal epithelium. most part retain their primitive roundness, or, being flattened where they touch, acquire a polyhedral figure, in which no one dimension remarkably predominates. Hence the above term was applied to this form of epithelium by Mr. Bowman.* But in some places the cells show a tendency to lengthen into columns and in others to flatten into tables, especially when this epithelium approaches the confines of one or other of the preceding varieties; in such cases it has been

* Cyclop. of Anat., art. Mucous Membrane.

Transitional epithelium.

named *transitional;* moreover, when the scaly and columnar varieties border upon one another, the figure of their particles is gradually changed, presenting various intermediate forms; in other words, the epithelium there puts on the transitional character, though it may be only for a very small space.

The greatest stretch of spheroidal epithelium is found in the urinary passages, where it succeeds the columnar epithelium of the urethra at the internal orifice of that canal, and lines the whole of the bladder, ureters, and pelves of the kidneys. It is found also in the excretory ducts of the mammary, perspiratory, and of many mucous glands, and a modification of the spheroidal epithelium lines the inmost secreting cavities, or commencing ducts of glands generally (fig. 20′). In this last-mentioned situation, the nucleated cells contain a large proportion of fine granular matter; in some cases even, the peculiar ingredients of the secretion may be recognised in them; and it is conceived, that they have a considerable share in preparing or separating these matters from the blood.

Fig. 20′.*

Ciliated epithelium.

Ciliated Epithelium. — In this form of epithelium, the particles, which are generally columnar, bear at their free extremities little hair-like processes, which are agitated incessantly during life, and for some time after death, with a lashing or vibrating motion. These minute and delicate moving organs are named *cilia.* They have now been discovered to exist very extensively throughout the animal kingdom; and the movements they produce are subservient to very varied purposes in the animal economy.

Where found.

In the human body the ciliated epithelium occurs in the following parts,† viz. :—1. On the mucous membrane of the air passages and its prolongations. It commences at a little distance within the nostrils, covers the membrane of the nose and of the adjoining bony sinuses, extends up into the nasal duct and lachrymal sac, is then interrupted by scaly epithelium which lines the lachrymal canals, but reappears on the conjunctiva of the eyelids. From the nose it spreads

* Cells from the liver magnified. (Dr. Baly.)

† Henle, Allgemeine Anatomie, p. 246.

backwards a certain way on the upper surface of the soft palate, and into the upper or nasal region of the pharynx; also into the Eustachian tube and tympanum. The remainder of the pharynx is covered by scaly epithelium as already mentioned; but the ciliated epithelium begins again in the larynx a little above the glottis, and continues throughout the trachea and the bronchial tubes in the lungs to their smallest ramifications. 2. On the mucous lining of the uterus, commencing at the middle of the cervix and Fallopian tubes, and even on the peritoneal surface of the latter at their fimbriated extremities. 3. On the parietes of the ventricles of the brain.*

Ciliary motion, how seen;

In other mammiferous animals, as far as examined, cilia have been found in nearly the same parts. To see them in motion, therefore, a portion of ciliated mucous membrane may be taken from the body of a recently killed quadruped. The piece of membrane is to be folded with its free or ciliated surface outwards, placed on a slip of glass, with a little water or serum of blood, and covered with a bit of thin glass or mica. When it is now viewed with a magnifying power of 200 diameters, or upwards, a very obvious agitation will be perceived on the edge of the fold, and this appearance is caused by the moving cilia with which the surface of the membrane is covered. Being set close together, and moving simultaneously or in quick succession, the cilia, when in brisk action, give rise to the appearance of a bright transparent fringe along the fold of the membrane, agitated by such a rapid and incessant motion, that the single threads which compose it cannot be perceived. The motion here meant, is that of the cilia themselves; but they also set in motion the adjoining fluid, driving it along the ciliated surface, as is indicated by the agitation of any little particles that may accidentally float in it. The fact of the conveyance of fluids and other matters along the ciliated surface, as well as the direction in which they are impelled, may also be made manifest by immersing the membrane in fluid, and dropping on it some finely pulverised substance, (such as charcoal in fine powder,) which will be slowly but steadily carried along in a constant and determinate direction; and this may be seen with the naked eye, or with the aid of a lens of low power.

causes a motion in fluid.

* This statement is made on the authority of Purkinje and Valentin, but Kölliker and Virchow failed to detect cilia in the cerebral ventricles of a recently executed criminal.

How seen in man.

The ciliary motion of the human mucous membrane is beautifully seen on the surface of recently extracted nasal polypi ; and single ciliated particles, with their cilia still in motion, are sometimes separated accidentally from mucous surfaces in the living body, and may be discovered in the discharged mucus ; or they may even be purposely detached by gentle abrasion. But the extent and limits of the ciliated epithelium of the human body have been determined chiefly from its anatomical characters.

Cilia found in many animals ; their use.

Cilia have now been shown to exist in almost every class of animals, from the highest to the lowest. The immediate purpose which they serve is, to impel matters, generally more or less fluid, along the surfaces on which they are attached ; or, to propel through a liquid medium the ciliated bodies of minute animals, or other small objects on the surface of which cilia are present ; as is the case with many infusorial animalcules, in which the cilia serve as organs of locomotion like the fins of larger aquatic animals, and as happens, too, in the ova of many vertebrated as well as invertebrate animals, where the yelk revolves in its surrounding fluid by the aid of cilia on its surface. In many of the lower tribes of aquatic animals, the cilia acquire a high degree of importance ; producing the flow of water over the surface of their organs of respiration, indispensable to the exercise of that function ; enabling the animals to seize their prey, or to swallow their food, and performing various other offices of greater or less importance in their economy. In man, and the warm-blooded animals, their use is apparently to impel secreted fluids or other matters, along the ciliated surface, as, for example, the mucus of the windpipe and nasal sinuses, which they carry towards the outlet of these cavities.

Fig. 21′.*

Structure of ciliated cells.

The cells of the ciliated epithelium (figs. 21′ and 22′), contain nuclei, as usual ; they have most generally an elongated or prismatic form, like the particles of the columnar epithelium, which they resemble too in arrangement, but are often of greater length, and have a

* Fig. 21′. Columnar ciliated epithelium cells from the human nasal membrane. Magnified 300 diameters.

finer extremity. The cilia are attached to their broad or superficial extremities, each columnar particle bearing a tuft of these minute hair-like processes. In some cases, the cells are spheroidal in figure, the cilia being still, of course, confined to that portion of the cell which forms part of the general surface of the epithelial layer (fig. 22′). Instances of the latter form occur in the epithelium of the frog's mouth, on the surface of the ovum, and, according to Valentin,† on the choroid plexuses of fœtal quadrupeds.

Fig. 22′.*

Of the cilia.

The cilia themselves differ widely in size in different animals, and they are not equal in all parts of the same animal. In the human windpipe they are, according to Valentin's measurement, $\frac{1}{4000}$th to $\frac{1}{2500}$th of an inch long; but in many invertebrate animals, especially such as live in salt water, they are a great deal larger. In figure they have the aspect of slender, conical, or slightly flattened filaments; broader at the base and usually pointed at their free extremity. Their substance is transparent, soft, and flexible. It is to all appearance homogeneous, and no fibres, granules, or other indications of definite internal structure, have been satisfactorily discovered in it.

Reproduction.

There is reason to believe that the ciliated epithelium of the uterus is from time to time shed and renewed; and, probably, the same change may take place, though more gradually and less perceptibly, on other ciliated surfaces. But the process by which this is effected is not satisfactorily known.

Gerlach states that a layer of long prismatic cells may be seen beneath the superficial and ciliated stratum and also filling up the spaces left between the pointed extremities of the latter. Underneath this layer there are small spheroidal cells and free nuclei. He supposes that spheroidal cells are developed around the free nuclei, and that the layer thus formed gradually replaces that upon which the cilia are found. This description applies to the epithelial coating of the human trachea.

Motions of cilia.

The manner in which the cilia move, is best seen when

* Fig. 22′. Spheroidal ciliated cells from the mouth of the frog. Magnified 300 diameters.

† Wagner's Handwörterbuch der Physiologie, art. Flimmerbewegung.

they are not acting very briskly. Most generally they seem to execute a sort of fanning or lashing movement; and when a number of them perform this motion in regular succession, as is generally the case, they give rise to the appearance of a series of waves travelling along the range of cilia, like the waves caused by the wind in a field of corn. When they are in very rapid action the undulation is less obvious, and, as Henle remarks, their motion then conveys the idea of swiftly-running water. The undulating movement may be beautifully seen on the gills of a mussel, and on the arms of many polypes. The undulations, with some exceptions, seem always to travel in the same direction on the same parts. The impulsion, also, which the cilia communicate to the fluids or other matters in contact with them, maintains a constant direction, unless in certain of the infusoria, and in these the motion has even been supposed to be voluntary. Thus in the windpipe of mammalia, the mucus is conveyed upwards towards the larynx, and if a portion of the membrane be detached, matters will still be conveyed along the surface of the separated fragment in the same direction relatively to that surface, as before its separation.

Direction of impulsion.

Inferences from its continuance after death.

The persistence of the ciliary motion for some time after death, and the regularity with which it goes on in parts separated from the rest of the body, sufficiently prove that, with the possible exceptions alluded to, it is not under the influence of the will of the animal nor dependent for its production on the nervous centres, and it does not appear to be influenced in any way by stimulation or sudden destruction of these centres. The time which it continues after death or separation differs in different kinds of animals, and is also materially influenced by temperature and by the nature of the fluid in contact with the surface. In warm-blooded animals the period varies from two or three hours to two days, or even more; being longer in summer than in the cold of winter. In frogs the motion may continue four or five days after destruction of the brain; and it has been seen in the gullet of the tortoise fifteen days after decapitation, continuing seven days after the muscles had ceased to be irritable.

Time of endurance.

Effect of external agents.

With the view of throwing further light on the nature of this remarkable kind of motion, experiments have been made to ascertain the effect produced on it by different external agents; but it would seem that, with the exception perhaps of moderate heat and cold, and alkaline solutions,

these agents affect the action of the cilia only in so far as they act destructively on their tissue.

The effect of change of temperature is different in warm and cold-blooded animals. In the former the motion is stopped by a cold of 43° F., whereas in the frog and river-mussel it goes on unimpaired at 32° F. E. H. Weber has made the interesting observation that in ciliated epithelium particles detached from the human nasal membrane, the motion which has become languid or quiescent from the cold, may be revived by warmth, such as that of the breath, and this several times in succession. A moderately elevated temperature, say 100° F., does not affect the motion in cold-blooded animals, but, of course, a heat considerably higher than this, and such as to alter the tissue, would put an end to it in all cases. Electric shocks, unless they cause abrasion of the ciliated surface (which is sometimes the case), produce no visible effect; and the same is true of galvanic currents. Fresh water, I find, arrests the motion in marine mollusca and in other salt-water animals in which I have tried its effect; but it evidently acts by destroying both the form and substance of the cilia, which in these cases are adapted to a different medium. Most of the common acid and saline solutions, when concentrated, arrest the action of the cilia instantaneously in all animals; but dilution delays this effect, and when carried farther, prevents it altogether; and hence it is, probably, due to a chemical alteration of the tissue. Virchow has observed that a solution of either potash or soda will revive the movement of cilia after it has ceased. Narcotic substances, such as hydrocyanic acid, salts of morphia and strychnia, opium and belladonna, are said by Purkinje and Valentin to have no effect, though the first-named agent has certainly appeared to me to arrest the motion in the river-mussel. Bile stops the action of the cilia while blood prolongs it in vertebrated animals; but the blood or serum of the vertebrata has quite an opposite effect on the cilia of invertebrate animals, arresting their motion almost instantaneously.

Heat and cold.

Electricity.

Fresh water.

Acids and salts.

Alkalies.

Narcotics.

Animal fluids.

Cause of ciliary motion.

It must be confessed that the nature and source of the power by which the cilia act are as yet unknown; but whatever doubt may hang over this question, it is plain that each ciliated cell is individually endowed with the faculty of producing motion, and that it possesses in itself whatever organic apparatus and whatever physical or vital property may be necessary for that end; for single epithelium cells are seen to exhibit the phenomenon long after they have been completely insulated.

Without professing to offer a satisfactory solution of a question beset with so much difficulty, it seems, nevertheless, not unreasonable to consider the ciliary motion as being probably a manifestation of that property on which the more conspicuous motions of animals are known to depend, namely, vital contractility; and this view has at least the advantage of referring the phenomenon to the operation of a vital property already recognised as a source of moving power in the animal body.

It is true that nothing resembling a muscular apparatus in the ordinary sense of the term, has been discovered to be connected with the cilia, nor is it necessary to suppose the existence of any such; for it must be remembered that vital contractility is not limited to a tissue strictly defined in its appreciable structure. The anatomical characters of human voluntary muscle differ widely from those of most involuntary contractile textures, and still more from the contractile tissues of some of the lowest invertebrate animals, although the movements must in all these cases be referred to the same principle. The heart of the embryo beats while yet but a mass of cells, united, to all appearance, by amorphous matter, in which no fibres are seen; yet no one would doubt that its motions depend then on the same property as at a later period, when its structure is fully developed.

In its persistence after systemic death and in parts separated from the rest of the body, the ciliary motion agrees with the motion of certain muscular structures, as the heart for example; and the agreement extends even to the regular or rhythmic character of the motion in these circumstances. It is true, the one endures much longer than the other; but the difference appears to be one only of degree, for differences of the same kind are known to prevail among muscles themselves. No one, for instance, doubts that the auricle of the heart is muscular, because it beats longer after death than the ventricle; nor, because a frog's heart continues to act a much longer time than a quadruped's, is it inferred that its motion depends on a power of a different nature. And the view here taken of the nature of the ciliary motion derives strength from the consideration that the phenomenon lasts longest in cold-blooded animals, in which vital contractility also is of longest endurance. In the effects of heat and cold, as far as observed, there is also an agreement between the movement of cilia and that of muscular parts. It must be allowed, unless we distrust the observations of very competent inquirers, that narcotic substances do not in general affect the cilia, while they are generally admitted to alter or extinguish muscular action. At the same time there remains some ambiguity on this head, and my own observations do not agree in all points with those referred to. Something, moreover, may depend on the facility or difficulty with which the tissues permit the narcotic fluid to penetrate, which circumstance must needs affect the rapidity and extent of its operation. In the effect of opium on the heart there is a great difference, according as the narcotic is applied to its outer or its inner surface; and to this must be added that the effect of narcotics has not been carefully tried on all contractile tissues. Again, we see differences in the mode in which the cilia themselves are affected by the same agent: thus fresh water instantly arrests their motion in certain cases, while it has no such effect in others.

The discovery of vibrating cilia on the spores and other parts of certain cryptogamic vegetables may perhaps be deemed a strong argument on the opposite side; but it is by no means proved that the sensible motions of plants (such, at least, as are not purely physical), and those of animals, do not depend on one common vital property.

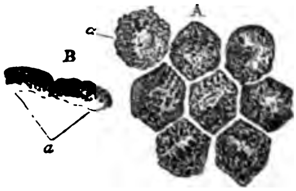
PIGMENT.

Where found.

The cells of the cuticle, and of other textures which more or less resemble it in structure, sometimes contain a black or brown matter, which gives a dark colour to the parts over which these cells are spread. A well-marked example of such pigment-cells in the human body is afforded by the black coating which lines the choroid membrane of the eye and covers the posterior surface of the iris. They are found in the epidermis of the Negro and other dark races of mankind, and in the more dusky parts of the cuticle of the European. They have been found also on certain parts of the investing membrane (pia mater) of the spinal cord, and in the membranous labyrinth of the ear.

Its structure in the eye.

Fig. 23′.*



The pigment-cells of the choroid membrane (fig. 23′) are for the most part polyhedral in figure, most generally six-sided, and connected together like the pieces of a mosaic pavement; others are spheroidal, and most of those on the back of the iris are of that shape. The cells contain the pigment, strictly so called, which consists of minute black or brown granules or molecules of a round or oblong shape, measuring not more than from $\frac{1}{17000}$ to $\frac{1}{24000}$ of an inch in their greatest dimension. These molecules are densely packed together in some cells; in others they are more scattered, and then it may be seen that there is a certain amount of colourless matter included along with them. When they escape from the ruptured cells, they exhibit very strikingly the molecular movement; and in consequence of this movement the apparent shape of the particles is subject to change. It is worthy of remark, that when viewed singly with a very high magnifying power they look transparent and almost colourless, and it is only when they

* Pigment-cells from the choroid, magnified 370 diameters. A. Cells still cohering, seen on their surface. *a*. Nucleus indistinctly seen. In the other cells the nucleus is concealed by the pigment granules. B. Two cells seen in profile. *a*. The anterior part containing scarcely any pigment. (Henle.)

are heaped together that their blackness distinctly appears. The cells have a colourless nucleus, which is very generally hidden from view by the black particles. It contains a central nucleolus.

Chemical nature.

Examined chemically, the black matter is found to be insoluble in cold and hot water, alcohol, ether, fixed and volatile oils, acetic and diluted mineral acids. Its colour is discharged by chlorine. The pigment of the bullock's eye, when purified by boiling in alcohol and ether, was found by Scherer to consist of 58·672 carbon, 5·962 hydrogen, 13·768 nitrogen, and 21·598 oxygen; its proportion of carbon is thus very large. Preceding chemists had obtained from its ashes oxide of iron, chloride of sodium, lime, and phosphate of lime.

Structure in the skin.

The dark colour of the negro is known to have its seat in the cuticle, and chiefly in the deeper and softer part named the rete mucosum. According to Henle, it is caused by the presence of pigment-cells, resembling those of the choroid in almost every respect save their size, which is somewhat less. These are intermixed with colourless cells, and on the proportion of the two the depth of colour of different parts depends. According to the same authority, the darker parts of the European skin owe their colour to pigment-cells like those of the Negro, only still smaller in size, less defined in their outline, and less numerous. Krause affirms that the dark colour of the cuticle both of the Negro and white races depends chiefly on the presence of cells which have dark brown nuclei, the substance of the cell being also tinged, but less deeply than the nucleus, and the colour being diffused through the mass and not caused by molecules. He admits that a few true pigment-cells exist in the Negro's skin; and while it is generally admitted, by Kölliker and others, that the pigment-molecules have a tendency to accumulate around the nucleus, it appears most probable that there is no essential difference between the coloured and white races, as to the source of colour of their cuticle; for whatever be the structure of the colouring particles, it cannot be doubted that in both cases the colouring matter of the skin is the same in its essential nature as that of the choroid. In Albino individuals, both of the Negro and European races, in whom the black matter of the choroid is wanting, the cuticle and the hair are colourless also.

In some situations the pigment-cells become irregular and jagged at their edges, or even branch out into long irregular

processes. Such ramified cells are very common in many animals, as those from the skin of the frog represented in fig. 9'. In the human body pigment-cells of this description are found in the dark cellular membrane between the sclerotic and choroid coats of the eye, and on the pia mater covering the upper part of the spinal cord. The condition of the pigment in the hairs will be afterwards described. Ramified pigment-cells.

From the observations of Valentin on the choroid membrane of the embryo bird, it appears that the pigment-cells are formed round previously existing nuclei, and that they are at first colourless, but that black molecules subsequently appear in them, first immediately round the nucleus, and afterwards throughout the rest of the cell. Development and regeneration.

When the cuticle of the Negro is removed by means of a blister, it is renewed again of its original dark hue; but if the skin be destroyed to any considerable depth, as by a severe burn, the resulting scar remains long white, though it at length acquires a dark colour.

In the eye the black matter seems obviously intended to absorb redundant light, and accordingly its absence in Albinos is attended with a difficulty of bearing a light of considerable brightness. Its uses in other situations are not so apparent. The pigment of the cuticle, it has been supposed, may screen the subjacent cutis from the pungency of the sun's rays, but in many animals the pigment is not only employed to variegate the surface of the body, but attaches itself to deep-seated parts. Thus, in the frog the branches and twigs of the blood-vessels are speckled over with it, and in many fish it imparts a black colour to the peritoneum and other internal membranes. Uses.

ADIPOSE TISSUE.

The human body in the healthy state contains a considerable amount of fatty matter of different kinds. Fat, as already mentioned, is found in the blood and chyle, and in the lymph, but much more sparingly. It exists, too, in several of the secretions, in some constituting the chief ingredient; and in one or other of its modifications it enters into the composition of certain solid textures. But by far the greater part of the fat of the body is inclosed in small cells or vesicles, which, together with their contained matter, constitute the adipose tissue. What.

This tissue is not confined to any one region or organ, but exists very generally throughout the body, accompanying the still more widely distributed cellular or areolar tissue Where found.

in most though not in all parts in which the latter is found. Still its distribution is not uniform, and there are certain situations in which it is collected more abundantly. It forms a considerable layer underneath the skin, and, together with the subcutaneous areolar tissue in which it is lodged, constitutes in this situation what has been called the *panniculus adiposus.* It is collected in large quantity round certain internal parts, especially the kidneys. It is seen filling up the furrows on the surface of the heart, and imbedding the vessels of that organ underneath its serous covering; and in various other situations it is deposited beneath the serous membranes, or is collected between their folds as in the mesentery and omentum, at first generally gathering along the course of the blood-vessels, and at length accumulating very copiously. Collections of fat are also common round the joints, lying on the outer surface of the synovial membrane, and filling up inequalities; in many cases, lodged, like the fat in the omentum, in folds of the membrane which project into the articular cavity. Lastly, the fat exists in large quantity within the bones, where it forms the marrow. On the other hand there are some parts in which fat is never found in the healthy condition of the body. Thus it does not exist in the subcutaneous areolar tissue of the eyelids and penis, nor in the lungs, nor within the cavity of the cranium.

Where absent.

Fig. 24′.*

Structure.

When subjected to the microscope, the adipose tissue (fig. 24′) is seen to consist of minute vesicles, filled with an oily

* A small cluster of fat-cells, magnified 150 diameters.

matter, and for the most part lodged in the meshes of the areolar tissue. The vesicles are most commonly collected into little lobular clusters, and these again into the little lumps of fat which we see with the naked eye, and which in some parts are aggregated into round or irregular masses of considerable magnitude. Sometimes the vesicles, though grouped together, have less of a clustered arrangement; as when they collect alongside of the minute blood-vessels of thin membranous structures.

In well-nourished bodies the vesicles or fat-cells are round **Fat-cells.** or oval, unless where packed closely together, in which case they acquire an angular figure, and bear a striking resemblance to the cells of vegetable tissues. The greater number of them are from $\frac{1}{300}$th to $\frac{1}{600}$th of an inch in diameter, but many exceed or fall short of this measurement. Each one consists of a very delicate envelope, inclosing the oily matter, which, completely filling the envelope, appears as a single drop. The envelope is generally quite transparent, and appears to be homogeneous in structure. In ill-nourished bodies, and especially in those presenting serous infiltration of the tissues (as in dropsy), different forms of fat-cells are observed. (1.) Granular, yellowish-white vesicles, containing **Granular.** numerous small fat globules. (2.) Yellow, or yellowish-red cells, filled with serum and globules of brownish- **Serum-holding.** yellow fat. The relative proportion of the serum and fat varies; but in all cases of this description Kölliker states that he has discovered a nucleus and nucleolus. The nucleus may be seen without re-agents, but is rendered more apparent by acetic acid. The vesicular envelope is found in different conditions. Sometimes it is normal; but it has been seen finer and also thicker than usual. When thickened it may present the appearance of either a single or a double contour. (3.) Fatless cells, with normal or thickened walls. **Fatless.** (4.) Fat-cells containing crystals, either yellow or white in **Crystalline.** colour. At first sight these cells appear filled with opaque and granular contents, but upon minute examination are seen to contain stelliform acicular crystals, though in some cases their aspect is very faintly granular.

Schwann discovered a nucleus in the fat-cells of the embryo; the nucleus contains one or two nucleoli, and is attached to the inside of the cell-wall or imbedded in its substance. Although nuclei have rarely been seen in the cells of well-nourished adipose tissue in after-life, Kölliker states that he invariably finds them when the fat has partially

disappeared, and thence infers that they are always present. This inference is confirmed by Bruch, who states that the endosmose of water always renders a nucleus apparent.

Chemical composition of fat.

The common fat of the human body may be represented as a mixture of a solid fatty substance named "margarin," and a liquid oily substance, "olein;" the suet or fat of oxen and sheep, on the other hand, consists chiefly of a second solid principle, "stearin," associated with olein. These three substances, margarin, olein, and stearin, are themselves compounds of a base named "glycerine" with three fatty acids respectively, the margaric, oleic, and stearic; while the glycerine is supposed to be the oxide (or hydrated oxide) of an hypothetical radical, "glyceryl."

Of crystals.

During life the only matter contained in the cells is liquid; but the crystalline spots which are sometimes seen after death indicate a partial solidification of one of its constituents. This has been supposed to be the margarin; but it appears from its chemical relations to be most probably margaric acid.

The fat being thus contained in closed cells, it will be readily understood why, though liquid or nearly so in the living body, it does not shift its place in obedience to pressure or gravitation, as happens with the water of dropsy and other fluids effused into the interstices of the areolar tissue; such fluids, being unconfined, of course readily pass from one place to another through the open areolæ.

The areolar tissue connects and surrounds the larger lumps of fat, but forms no special envelope to the smaller clusters; and although fine fasciculi and filaments of that tissue pass irregularly over and through the clusters, yet it is probable that the vesicles are held together in these groups mainly by the fine network of capillary vessels distributed to them. In the marrow the areolar tissue is very scanty; indeed the fat-cells in some parts of the bones are said to be altogether unaccompanied by areolar filaments.

Vessels.

The adipose tissue is copiously supplied with blood-vessels. The larger branches of these pass into the fat lumps, where they run between the lobules and subdivide, till at length a little artery and vein are sent to each small lobule, dividing into a network of capillary vessels, which not only surrounds the cluster externally, but passes through between the vesicles in all directions, supporting and connecting them. The lymphatics of the fat, if it really possess

any, are unknown. Nor have nerves been seen to terminate in it, though nerves destined for other textures may pass through it. Accordingly it has been observed that, unless when such traversing nervous twigs happen to be encountered, a puncturing instrument may be carried through the adipose tissue without occasioning pain. Nerves.

As to the uses of the fatty tissue, it may be observed, in the first place, that it serves the merely mechanical purpose of a light, soft, and elastic packing material to fill vacuities in the body. Being thus deposited between and around different organs, it affords them support, facilitates motion, and protects them from the injurious effects of pressure. In this way, too, it gives to the exterior of the body its smooth rounded contour. Further, being a bad conductor of heat, the subcutaneous fat must so far serve as a means of retaining the warmth of the body, especially in warm-blooded creatures exposed to great external cold, as the whale and other cetaceous animals, in which it forms a very thick stratum, and must prove a much more effectual protection than a covering of fur in a watery element. Uses.

But the most important use of the fat consists in subserviency to the process of nutrition. Composed chiefly of carbon and hydrogen, it is absorbed into the blood and consumed in respiration, combining with oxygen to form carbonic acid and water, and thus contributing with other hydrocarbonous matters to maintain the heat of the body; and it is supposed that when the digestive process introduces into the system more carbon and hydrogen than is required for immediate consumption, the excess of these elements is stored up in the form of fat, to become available for use when the expenditure exceeds the immediate supply. According to this view, active muscular exercise, which increases the respiration, tends to prevent the accumulation of fat by increasing the consumption of the hydrocarbonous matter introduced into the body. Again, when the direct supply of calorific matter for respiration is diminished or cut off by withholding food, or by interruption of the digestive process, nature has recourse to that which has been reserved in the form of fat; and in the wasting of the body caused by starvation, the fat is the part first consumed.

The use of the fat in nutrition is well illustrated by what occurs in the hedgehog and some other hybernating animals. In these the function of alimentation is suspended during their winter sleep, and though their respiration is reduced to the lowest amount compatible with life, and their temperature falls, there is yet a considerable amount of hydrocarbonous material provided in the shape of fat before their hybernation commences, to be slowly consumed during that period, or perhaps to afford an immediate supply on their respiration becoming again active in spring.

It has been estimated that the mean quantity of fat in the human subject is about one-twentieth of the weight of the body, but from what has been said, it is plain that the amount must be subject to great fluctuation. The proportion is usually largest about the middle period of life, and greatly diminishes in old age. High feeding, repose of mind and body, and much sleep, favour the production of fat. To these causes must be added individual and perhaps hereditary predisposition. There is a greater tendency to fatness in females than Quantity.

males, also, it said, in eunuchs. The effect of castration in promoting the fattening of domestic animals is well known.

Differences in situation.

In infancy and childhood the fat is confined chiefly to the subcutaneous tissue. In after-life it is more equally distributed through the body, and in proportionately greater quantity about the viscera. In Hottentot females fat accumulates over the gluteal muscles, forming a considerable prominence, and in a less degree over the deltoid; a tendency to local accumulations of the subcutaneous fat is known to exist also in particular races of quadrupeds.

Development.

Development.—According to Valentin, the fat first appears in the human embryo about the fourteenth week of intra-uterine life. At this period the fat-cells are insulated, but by the end of the fifth month they are collected into small groups. When first seen, they are also of comparatively small size. As already stated, the fœtal fat-cells contain a nucleus in their early condition which is afterwards hidden from view; but it is not certain that the nucleus precedes and gives rise to the cell.

It has been a question whether, when the fat undergoes absorption, the vesicles are themselves consumed along with their contents. Dr. W. Hunter believed that they still remained after being emptied; he was led to this opinion by observing the condition of the areolar tissue in dropsical bodies from which the fat had disappeared, there being in such cases a marked difference in aspect between the parts of that tissue which had originally contained fat and those which had not, which difference he attributed to the persistence of the empty fat vesicles. Gurlt states that the fat-cells in emaciated animals are filled with serum, and this statement is fully confirmed by the observations of Kölliker, Todd and Bowman, myself, and others.

THE AREOLAR, CELLULAR, OR CONNECTIVE TISSUE.

Names applied to it; where found.

If we make a cut through the skin and proceed to raise it from the subjacent parts, we observe that it is loosely connected to them by a soft filamentous substance, of considerable tenacity and elasticity, and having, when free from fat, a white fleecy aspect; this is the substance known by the names of "cellular," "areolar," "filamentous," "connective," and "reticular" tissue; it is often also called "cellular membrane." In like manner the areolar tissue is found underneath the serous and mucous membranes which are spread over various internal surfaces, and serves to attach these membranes to the parts which they line or invest; and as under the skin it is named "subcutaneous," so in the last-mentioned situations it is called "subserous" and "submucous" areolar tissue. But on proceeding

further we find this substance lying between the muscles, the blood-vessels, and other deep-seated parts, occupying, in short, the intervals between the different organs of the body where they are not otherwise insulated, and thence named "intermediate;" very generally, also, it becomes more consistent and membranous immediately around these organs, and, under the name of the "investing" areolar tissue, affords each of them a special sheath. It thus forms inclosing sheaths for the muscles, the nerves, the blood-vessels, and other parts. Whilst the areolar tissue might thus be said in some sense both to connect and to insulate entire organs, it also performs the same office in regard to the finer parts of which these organs are made up; for this end it enters between the fibres of the muscles, uniting them into bundles; it connects the several membranous layers of the hollow viscera, and binds together the lobes and lobules of many compound glands; it also accompanies the vessels and nerves within these organs, following their branches nearly to their finest divisions, and affording them support and protection. This portion of the areolar tissue has been named the "penetrating," "constituent," or "parenchymal."

It thus appears that the areolar is one of the most general and most extensively distributed of the tissues. It is, moreover, continuous throughout the body, and from one region it may be traced without interruption into any other, however distant; a fact not without interest in practical medicine, seeing that in this way dropsical waters, air, blood, and urine, effused into the areolar tissue, and even the matter of suppuration, when not confined in an abscess, may spread far from the spot where they were first introduced or deposited. Continuity.

On stretching out a portion of areolar tissue by drawing gently asunder the parts between which it lies, it presents an appearance to the naked eye of a multitude of fine soft elastic threads, quite transparent and colourless, like spun glass; these are intermixed with fine transparent films, or delicate membranous laminæ, and both threads and laminæ cross one another irregularly and in all imaginable directions, leaving open interstices or areolæ between them. These areolæ are, of course, more apparent when the tissue is thus stretched out; it is plain also that they are not closed cells, as the term "cellular tissue" might seem to imply, but merely interspaces, which open freely into one another: Structure as seen with naked eye. Areolæ.

many of them are occupied by the fat, which, however, as already explained, does not lie loose in the areolar spaces, but is enclosed in its own vesicles. A small quantity of colourless transparent fluid is also present in the areolar tissue, but, in health, not more than is sufficient to moisten it. This fluid is generally said to be of the nature of serum; but it is not improbable that, unless when unduly increased in quantity or altered in nature by disease, it may resemble more the liquor sanguinis, as is the case with the fluid of most of the serous membranes.

Fluid.

Varieties.

On comparing the areolar tissue of different parts, it is observed in some to be more loose and open in texture, in others more dense and close, according as free movement or firm connexion between parts is to be provided for. In some situations, too, the laminæ are more numerous; in others the filamentous structure predominates, or even prevails exclusively; but it does not seem necessary to designate these varieties by particular names, as is sometimes done.

Microscopic characters.

When examined under the microscope, the areolar tissue is seen to be principally made up of exceedingly fine, transparent, and apparently homogeneous filaments, from about $\frac{1}{15000}$th to $\frac{1}{25000}$th of an inch in thickness, or even less (fig. 25'). These are seldom single, being mostly united by means of a small quantity of clear, homogeneous connecting substance into bundles and filamentous laminæ of various sizes, which, to the naked eye, appear as simple threads and films. Though the bundles may intersect in every direction, the filaments of the same bundle run nearly parallel to each other, and no one filament is ever seen to divide into branches or to unite with another. The associated filaments take an alternate bending or waving course as they proceed along the bundle, but still maintain their general parallelism. This wavy aspect, which is very characteristic of these filaments, disappears on stretching the bundle, but returns again when it is relaxed.

White filaments.

The filaments just described, though transparent when seen with transmitted light under the microscope, have a white colour when collected in considerable quantity and seen with reflected light; and they not only occur in the areolar tissue strictly so called, but form the chief part of the tendons, ligaments, and other white fibrous textures. They were long supposed to be the only fibrous constituent existing in the areolar tissue, but it has been shown (and

chiefly through the inquiries of Eulenberg, Henle, and Bowman) that fibres of another kind are intermixed with

Fig. 25'.*

them; these either are identical with the fibres of the yellow elastic tissue, or at least approach them very closely in character, and they have accordingly been named the yellow or elastic fibres, to distinguish them from the white or waved filaments above described. They were termed nuclear fibres (Kernfasern) by Gerber and Henle, on account of their supposed origin from nuclei; but as this opinion is at best but doubtful, the former appellation seems preferable.

Yellow fibres.

In certain portions of the areolar tissue, as for instance in that which lies under the serous and mucous membranes of particular regions, the yellow or elastic fibres are large and abundant, so that they cannot well be overlooked; but in other parts they are few in number, and small, and are then in a great measure hidden by the white filaments; in such cases, however, they can always be rendered conspicuous under the microscope by means of acetic acid, which causes the white

* Fig. 25'. Filaments of areolar tissue, in larger and smaller bundles, as seen under a magnifying power of 400 diameters. Two or three corpuscles are represented among them.

filaments to swell up and become indistinct, whilst the yellow fibres, not being affected by that reagent, come then more clearly into view (fig. 26′). Under the microscope

Fig. 26′.*

these fibres appear transparent and colourless, with a strong, well-defined, dark outline. They are, moreover, remarkable for their tendency to curl up, especially at their broken ends, which gives them a very peculiar aspect (*b*), and in many parts of the areolar tissue they divide into branches and join or anastomose with one another, in the same manner as in the pure elastic tissue (*a*). They differ among themselves very widely in size, some being as fine as the white filaments, others many times larger. They lie for the most part without order among the bundles of white filaments ; but here and there we see an elastic fibre, generally of great tenuity, winding round one of these bundles, and encircling it with several spiral turns. When acetic acid is applied, the fasciculus swells out between the constricting turns of the winding fibre, and presents a highly characteristic appearance (*c*). This remarkable disposition of the elastic fibres, which was pointed out by Henle, is not uncommon in certain parts of the areolar tissue ; it may be

* Fig. 26′. Magnified view of areolar tissue (from different parts) treated with acetic acid. The white filaments are no longer seen, and the yellow or elastic fibres with the nuclei come into view. At *c*, the elastic fibres wind round a bundle of white fibres, which is swollen out between the turns.

always seen in that which accompanies the arteries at the base of the brain.

Corpuscles.

A few rounded and oval corpuscles (fig. 25′) and irregular particles are now and then met with in the interstices of the tissue, and others are seen attached to the surface of the filamentous bundles, or in their interior. The former are probably to be considered as belonging to the interstitial fluid. The latter, which are best seen after the application of acetic acid (fig. 26′), are generally supposed to be of the nature of cell nuclei; many of them are elongated and attenuated, and they often appear disposed in longitudinal series on the surface of, or within the fasciculi (*c*).

In reference to the constitution of areolar tissue, it may be further remarked, that there are other textures of the body which are made up of the same elements; the tendons and ligaments, the periosteum, and other fibrous membranes, belong to this class.

Reichert's opinion of structure.

A very different view of the structure of areolar tissue has been taken by Reichert, and adopted by Virchow, Donders, and other distinguished histologists. It is maintained that the apparent bundles consist of a tissue in reality amorphous or homogeneous, and that its seeming fibrillation is partly artificial, the result of cleavage, and partly an optical illusion, arising from creasing or folding. Certain cellular bodies with stellate processes lying upon and within this homogeneous matrix have been described by Virchow, and denominated "corpuscles of the connective tissue" (Bindegewebskörperchen). Thus, the areolar tissue is considered homologous with the intercellular substance of cartilage; and the corpuscles, which appear to be continuous with the elastic fibres, are looked upon as corresponding to the cartilage-cells. On the other hand it is asserted by Henle, with whom Bruch agrees, that these so-called corpuscles are nothing more than vacuities among the fibres. In reference to the above view, which is still matter of controversy, it may be observed that fasciculi very probably occur, of which the fibrillation is incomplete, but there does not seem to be sufficient reason for denying that the bundles of the tissue generally are made up of real filaments.

Chemical composition.

The areolar tissue contains a considerable quantity of water, and consequently loses much of its weight by drying. It is almost wholly resolved into gelatine by boiling in water. Acetic acid causes it to swell up into a soft, transparent, jelly-like mass.

Blood-vessels and lymphatics. Numerous blood-vessels are seen in the areolar tissue after a minute injection. These for the most part only pass through it on their way to other more vascular textures, but a few seem to end in capillaries destined for the tissue itself, and dense clusters of vessels are distributed to the fat lobules. Large lymphatic vessels proceeding to distant parts also pass along this texture, and abundant lymphatic networks may be discovered in many parts of the subcutaneous, subserous, and submucous areolar tissue, having evident relation to the function of the membranes under which they lie. Absorption readily takes place from the interstices of the texture, but that process may be effected through the agency of blood-vessels as well as of lymphatics.

Nerves. Larger and smaller branches of nerves also traverse this tissue on their way to other parts; but it has not been shown that any remain in it, and accordingly it may be cut in a living animal apparently without giving pain, except when the instrument meets with any of these traversing branches. It is not improbable, however, that nerves end in those parts of the areolar tissue which, like that of the scrotum, contain contractile fibres; but, if present in such cases, the nerves, like the vessels of the fat, are, after all, destined not to the areolar tissue but to another mixed with it.

Physical and vital properties. The physical properties of this texture have been sufficiently indicated in the foregoing description; also its want of sensibility. The vital contractility ascribed to certain portions of it is most probably due to the presence of muscular fibres.

Development. The areolar tissue is developed from a blastema containing cells or nuclei, but the process is not yet fully understood. Schwann supposed that the cells lengthened out and then split up into bundles of fibrils. It has subsequently been more generally held that the white fasciculi are produced by fibrillation of bands formed by the intercellular blastema, whilst the yellow or elastic fibres are generated by the elongation, ramification, and union of the cells. Kölliker, however, entertains a view more in accordance with that of Schwann. He calls attention to the fact that in young or nascent areolar tissue there is a large amount of a soft substance of gelatinous aspect, though not allied to gelatine in its chemical nature. Part of the cells contained in this soft matter are lengthened out and break up into the white fibrils of the future tissue; and in this way a network results, in the meshes of which the soft substance or matrix and the remainder of the formative cells are contained. New cells then proceed from the matrix, which thereby diminishes in quantity, and fresh bundles of tissue are formed from the cells. Another portion of the cells become lengthened out, ramified,

and connected together, and thus give rise to the yellow or elastic fibres. The soft matrix finally disappears from the areolar tissue generally; but in that which is contained in the umbilical cord and between the chorion and amnion, it remains, and in the former situation has been long known as the "jelly of Wharton." We may here add that the areolar tissue undergoes a change in chemical nature in the course of its development; for when the immature tissue is boiled in water, even for a long time, a considerable part remains undissolved, and the matter extracted from it is not gelatin, but agrees very nearly in chemical characters with the animal principle named "pyin." Perfectly-formed areolar tissue is found in the spinal region and some other parts, as early as the beginning of the fourth month of intra-uterine life; but fasciculi are met with even in the adult, in which it seems probable that fibrils are not completely developed; in such cases the bundle appears to be merely striped or fluted longitudinally, and not divided into distinct threads.

Regeneration.

With the exception of epithelium, no tissue is so readily regenerated as the areolar. The process of reproduction seems to be essentially the same as that of its original formation in the embryo, the blastema being in this case derived from the blood in form of effused lymph. In this way areolar tissue is formed in the healing of wounds and in the adhesion of inflamed surfaces. It is produced also in many morbid growths.

FIBROUS TISSUE.

General nature and uses.

This substance is one of those which are serviceable in the body on account of their mechanical properties, being employed to connect together or to support and protect other parts. It is met with in the form of ligaments, connecting the bones together at the joints; it forms the tendons of muscles, into which their fleshy fibres are inserted, and which serve to attach these fibres to the bones. In its investing and protecting character it assumes the membranous form, and constitutes a class of membranes termed "fibrous." Examples of these are seen in the periosteum and perichondrium which cover the bones and cartilages, in the dura mater which lines the scull and protects the brain, and the fibrous layer which strengthens the pericardium, also in the albugineous coat of the testicle and ovary, and the sclerotic coat of the eye, which inclose the tender internal parts of these organs. Fibrous membranes, named "aponeuroses" or "fasciæ," are also employed to envelope and bind down the muscles of different regions, of which the great fascia inclosing the muscles of the thigh and leg is a well-known example. The tendons of muscles, too, may assume the expanded form of aponeuroses, as those of the broad muscles of the abdomen, which form strong fibrous layers in the walls

Exists in two chief forms.

of that cavity and add to their strength. It thus appears that the fibrous tissue presents itself under two principal forms, the *fascicular* and the *membranous*.

Physical properties.

Physical Properties.—The fibrous tissue is white or yellowish white, with a shining, silvery, or nacreous aspect. It is exceedingly strong and tough, yet perfectly pliant; but it is almost devoid of extensibility. By these qualities it is admirably suited to the purposes to which it is applied in the animal frame. By its inextensible character it maintains in apposition the parts which it connects against any severing force short of that sufficient to cause actual rupture, and this is resisted by its great strength, whilst its flexibility permits of easy motion. Accordingly the ligaments and tendons do not sensibly yield to extension in the strongest muscular efforts; and though they sometimes snap asunder, it is well known that bones will break more readily than tendons of equal thickness. The fibrous membranes are proportionally strong and alike inextensible; they will gradually yield, it is true, when the extending force acts slowly and for a long time, as when tumours or fluids slowly gather beneath them; but perhaps this gradual extension is accompanied with some nutritive change affecting the properties of the tissue.

Structure.

Structure.—The fibrous tissue is made up of fine filaments, agreeing in all respects with the white filaments of the areolar tissue already described. Like these they are collected into bundles, in which they run parallel and exhibit the same wavy character, cohering very intimately. The bundles appear to the naked eye as fine shining threads or narrow flattened bands, for they vary greatly in thickness. They either run all in one direction as in long tendons, or intersect each other in different planes as in some aponeuroses, or they take various directions and decussate irregularly with each other as in the dura mater. A variable amount of dense areolar tissue lies between the larger fasciculi; very little in tendons, more in some fibrous membranes. The filaments swell up and become indistinct when acted on by acetic acid, like those of areolar tissue, and here also the acid discloses the existence of nuclei, and of elastic fibres, intermixed in small proportion with the rest of the tissue.

Streaked aspect.

The surface of a tendon or of any other part consisting of this texture, appears marked across the direction of the fasciculi with alternate light and dark streaks, which give it

a peculiar aspect, not unlike that of a watered ribbon. This appearance is owing to the wavy course of the filaments, for when the light falls on them their bendings naturally give rise to alternate lights and shadows.

The fibrous and areolar tissues thus agreeing in their ultimate structure, it is not to be wondered at that sometimes the limits between the two should be but ill defined, and that the one should pass by inconspicuous gradations into the other. Instances of such a transition may be seen in many of the fasciæ; these at certain parts consist of dense areolar tissue, but on being traced farther are seen gradually to take on the fibrous character; and we often see that fasciæ which in one body are merely areolar are decidedly fibrous in another. Transition into areolar tissue.

In chemical constitution also the fibrous tissue is similar to the areolar. It contains about two-thirds of its weight of water; it becomes transparent, hard, and brittle, when dried, but readily imbibes water again and regains its original properties. It is resolved into gelatin by boiling. Chemical composition.

The fibrous tissue receives blood-vessels, but in general they are inconsiderable both in number and size compared with the mass of tissue to which they belong. In tendons and ligaments with longitudinal fasciculi, the chief branches of the vessels run parallel with and between the larger fasciculi, and, sending communicating branches across them, eventually form a very open network with large oblong meshes. Some fibrous membranes, as the periosteum and dura mater, are much more vascular; but the vessels seen in these membranes do not strictly belong to them, being destined for the bones which they cover. The lymphatics of fibrous tissue are not sufficiently known to be spoken of with certainty. Blood-vessels.

As to nerves, their general existence in this texture has not been satisfactorily demonstrated by anatomical investigation. Recent inquiries into this subject have shown that the smaller tendons contain no nerves, and the larger only such nervous filaments as accompany and belong to the vessels; and the same is true of the ligaments. The fasciæ and the sheaths of tendons are also destitute of nerves. On the other hand, fine nerves have been traced in the interosseous membrane of the leg, and nervous filaments are even abundant in the periosteum, but the majority of them do not belong to the membrane itself, but are destined for the subjacent bone. Nerves have also been traced in the dura Nerves and sensibility.

mater ; some accompany the vessels, others appear destined for the membrane itself, and others again for the bones.

It has been proved by numerous observations and experiments, that the tendons, ligaments, and other structures composed of fibrous tissue, are, in the healthy state, quite insensible ; but then it is known, on the other hand, that they occasion severe pain when inflamed, which cannot well be accounted for on the supposition that they are entirely destitute of nerves. Bichat, while he admitted their insensibility to cutting, burning, and most other kinds of stimuli which cause pain in sensible textures, ascribed to them a peculiar sensibility to twisting or to violent extension, and this opinion has been supported by other authorities of weight, but the proofs of it are not clear.

Development. This texture is developed in the same manner as the areolar. It is said to want at first its shining aspect, and in its early condition it is more vascular than afterwards.

Reunion and regeneration. It readily heals and unites when divided, as is seen in cases of broken tendo Achillis. From experiments on the lower animals, it appears that blood is effused in the first instance, but soon gives place to coagulable lymph, which surrounds the divided ends of the tendon and fills up the space between them. Fibres and blood-vessels are then formed in the lymph, probably in the same manner as in the original process of development, and the uniting mass gradually acquires consistence. Its fibres are irregularly interwoven, and it wants the lustre of the rest of the tendon, but is equally strong. Fibrous tissue is very generally produced as a uniting medium of broken bones when osseous union fails to take place ; it is common as a diseased production in various kinds of tumours.

YELLOW OR ELASTIC TISSUE.

Nature. Whilst the fibrous tissue is remarkable for its want of extensibility, and owes its usefulness as a constituent of the frame in a great measure to this circumstance, the substance we have now to consider is characterised by possessing this property in a very high degree, and is employed wherever an extensible and highly elastic material is required in the animal structure.

Where found. Examples of this texture on a large scale are seen in the horse, ox, elephant, and other large quadrupeds, in which it

forms the great elastic ligament, called ligamentum nuchæ, that extends from the spines of the vertebræ to the occiput, and aids in sustaining the head; in the same animals it also forms an elastic subcutaneous fascia, which is spread over the muscles of the abdomen and assists in supporting the contents of that cavity. In the human body it is met with chiefly in the following situations, viz. :—

1. Forming the ligamenta subflava, which extend between the arches of adjacent vertebræ; these ligaments, while they permit the bones to be drawn apart in flexion of the body, aid in restoring and maintaining their habitual approximation in the erect posture,—so far, therefore, relieving the constant effort of the erector muscles. 2. Constituting the chief part of the stylohyoid, thyrohyoid, and cricothyroid ligaments, those named the vocal cords, and the suspensory ligament of the penis. Also extending, in form of longitudinal bands, underneath the mucous membrane of the windpipe and its ramifications. 3. Entering, along with other textures, into the formation of the coats of the blood-vessels, especially the arteries, and conferring elasticity on these tubes. 4. Beneath the mucous membrane of the gullet and lower part of the rectum, also in the tissue which surrounds the muscular coat of the gullet externally. 5. In the tissue which lies under the serous membranes in certain parts. 6. In many of the fasciæ, where it is mixed with much areolar tissue. 7. In considerable quantity in the tissue of the skin.

Physical properties.

The elastic tissue in its purest and most typical condition, such as is seen in the ligamentum nuchæ of quadrupeds and the ligamenta subflava of the human spine, has a yellow colour more or less decided; it is extensible and elastic in the highest degree, but is not nearly so strong as ordinary fibrous ligament, and it breaks across the direction of its fibres when forcibly stretched. Its fibres may be easily torn separate in a longitudinal direction; they are often gathered into irregular fasciculi which run side by side but join at short distances with one another, and are further connected by areolar tissue, which is always intermixed with them in greater or less quantity. Elastic ligaments are also covered outwardly with a sheath of areolar tissue.

Microscopic characters.

When the elastic fibres are mixed up with a large proportion of some other kind of tissue, their yellow colour may not appear, but they can always be recognised by their microscopic characters. When viewed under a tolerably high magnifying power, they appear quite transparent, with a remarkably well-defined dark outline (fig. 27'). They run side by side, following a somewhat bending course, but with bold and wide curves, unlike the undulations of the white

the constraining force is withdrawn. By reason of these mechanical properties, it is rather extensively used in the construction of the body. Its specific gravity is 1·15.

Where found. Temporary cartilage.

In the early embryo the skeleton is, in great part, cartilaginous; but the cartilage forming its different pieces, which have the outward form of the future bones, in due time undergoes ossification or gives place to bone, in the greater part of its extent at least, and hence this variety of cartilage is named "temporary."

Permanent cartilages.

Of the permanent cartilages a great many are in immediate connexion with bone, and may be still said to form part of the skeleton. The chief of these are the articular and the costal cartilages; the former cover the ends or surfaces of bones in the joints, and afford these harder parts a thick springy coating, which breaks the force of concussion and gives ease to their motions; the costal or rib-cartilages form a considerable part of the solid framework of the thorax, and impart elasticity to its walls. Other permanent cartilages enter into the formation of the external ear, the nose, the eyelids, the eustachian tube, the larynx, and the windpipe. They strengthen the substance of these parts without undue rigidity; maintaining their shape, keeping open the passages through them where such exist, and giving attachment to moving muscles and connecting ligaments. Many of these have the form of plates or lamellæ of greater or less thickness, and have thence been called "membraniform cartilages;" but to some of them the term is scarcely applicable.

Perichondrium.

Cartilages, except those of the joints, are covered externally with a fibrous membrane named the *perichondrium.*

Intimate structure.

When a very thin slice of cartilage is examined with the microscope, it is seen to consist of nucleated cells disseminated in a solid mass or matrix. (Figs. 28′, 29′, and 30′.)

Matrix.

The matrix is sometimes transparent, and to all appearance homogeneous; in other instances it is dim and faintly granular, like ground glass, and in some varieties of cartilage it is pervaded by fine fibres.

Cells or corpuscles.

The cells, named also cartilage corpuscles, are contained in hollow cavities, or lacunæ, in the matrix; and occasionally they do not fill these lacunæ, so that there is seen a vacant space between the cartilage cells and their containing cavity. In some instances the cavity appears to be lined by a fine, homogeneous membrane.

Brandt and Bruch maintain that this apparent membranous lining is the result of optical illusion. Huxley, Leidy, and Remak are of opinion that it is only the limiting surface of the intercellular substance; whereas Kaufmann has recently stated, that by boiling for some hours, the membrane may be distinctly demonstrated, although invisible before; and that by treating the boiled cartilaginous tissue with diluted sulphuric acid, the intercellular substance may be entirely destroyed, the membranes remaining, with those enclosed elements, which, in the fresh state, were seen as the contents of the cartilage cavity.

The discovery of the "primordial utricle" of Mohl, and the demonstration of continuity between the vegetable true cell-wall and the intercellular substance, have modified the views entertained as to the signification of the cartilage-cell, and Remak and Leidy have accordingly maintained that the cartilage corpuscle is homologous with this primordial utricle. Mr. Huxley, who has discussed the question in a very interesting manner in the paper already cited, carries out the analogy to its furthest point, by urging that the limitary substance of the cartilage cavity is continuous with the chondrinous intercellular matrix, which he proposes to term "periplast," and homologous with the cellulose-wall of the vegetable tissues. The vesicular body contained within the periplast, Mr. Huxley names the "endoplast," and he fully agrees with Remak and Leidy in considering it to be the homologue of the primordial utricle, with its granular contents, and nucleus.

Nuclei of the cartilage-cells.

The nuclei, which may vary from $\frac{1}{2400}$ to $\frac{1}{4000}$ of an inch in diameter, are round, oval, angular, or irregular. They are granulated or smooth on the surface, and they sometimes, though not often, exhibit one or two nucleoli. Sometimes the nucleus contains fat globules, or is entirely converted into fat. It is often difficult to say whether a body contained within a cartilage-cell is its nucleus, or merely the granular contents which have shrunk away from its sides and formed a mass of the same shape as the cavity itself, in which the true nucleus is concealed.

Arrangement of the cells.

The cells are rarely dispersed singly in the matrix; they usually form groups of different shapes and sizes. Towards the surface of the cartilage the groups are generally flattened conformably with the surface (fig. 29′), appearing narrow and almost linear when seen edgeways, as in a perpendicular section. (Fig. 28′, *a.*) The cells in a group have a straight outline where they adjoin or approach one another, but at the circumference of the group their outline is rounded.

Such is the structure of cartilage in general, but it is more or less modified in the several varieties of the tissue.

Structure of articular cartilages.

In articular cartilage, the matrix in a thin section appears dim, like ground glass, and has an almost granular aspect. The cells and nuclei are small; the latter are commonly

vesicular, and parent-cells may frequently be seen enclosing two, four, or even more younger cells. The groups which they form are flattened at and near to the surface and lie parallel with it (fig. 28′, *a*, and fig. 29′) ; deeper and nearer

Fig. 28′.*

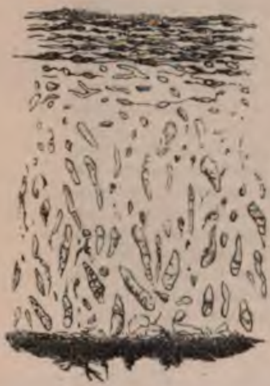


Fig. 29′.†

the bone, on the other hand, they are narrow and oblong, like short strings of beads, and are mostly directed vertically. (Fig 28′, *b* ; fig. 30′.) It is well known that articular cartilages readily break in a direction perpendicular to their surface, and the surface of the fracture appears to the naked eye to be striated in the same direction, as if they had a columnar structure ; this has been ascribed to the vertical arrangement of the rows of cells ; but, in fact, both the arrangement of the cells and the direction of the fracture are the result of a fibrous or columnar structure, latent in the matrix (Leidy). The free surface of articular cartilage

Epithelium. is said to be covered with epithelium continued from that of the synovial membrane, a thin stratum of areolar tissue being interposed ; but the existence of such a covering is

* Diagram representing a vertical section of articular cartilage, seen with a low magnifying power. *a*. Flattened groups of cells near the surface. *b*. Oblong groups, for the most part directed vertically. *c*. Part of the bone.

† A thin layer peeled off from the surface of the cartilage of the head of the humerus, showing flattened groups of cells. The nuclei are distinctly seen, but the limits of the cells where they adjoin one another are but faintly indicated. Magnified 400 diameters.

certainly not general, at least in the adult. It is easy, no doubt, to peel off a thin film from the surface of the cartilage

Fig. 30'.*

of the head of the humerus or femur; but this superficial layer is really part of the cartilage, and its broad patches of cells with the intermediate matrix are not to be mistaken. (See fig. 29'.) At the same time, it is true that near the margin of these cartilages a layer of fine filamentous tissue, covered with epithelium, is prolonged a certain way over their surface from the synovial membrane. The matrix of articular cartilage, rarely, or perhaps never, becomes pervaded by fibres like those seen in rib-cartilage, nor is it prone to ossify.

Structure of costal cartilages.

In the cartilages of the ribs, the corpuscles or cells which are of large size, are also collected into groups. Near the exterior of the cartilage they are flattened, and lie parallel with the surface, forming a superficial stratum from $\frac{1}{200}$ to $\frac{1}{300}$ of an inch thick. As to those situated more inwardly, we can sometimes observe, in a transverse slice, that they form oblong groups disposed in lines radiating to the circum-

* Vertical section of articular cartilage of the head of the humerus. A deep portion near the bone. Magnified 400 diameters. Each cell contains a mass shaped like itself, in the midst of which a round nucleus is probably concealed.

ference ; but this arrangement is not constant, and they often appear quite irregular. The cells, with the exception of those lying upon the surface, commonly contain larger or smaller drops of oil ; and the nucleus being generally undiscoverable, it is supposed to have undergone a fatty metamorphosis. The matrix is tolerably clear, except where fibres have been developed in it, in which parts it is opaque and yellowish. Such fibrous patches are very frequent ; the fibres are fine, straight, and parallel, appearing transparent when few together ; they withstand the action of acetic acid. It is common to find the rib cartilages extensively ossified.

It was observed by Herissant * that the costal cartilages, after many months' maceration in putrid water, would sometimes break up into thin plates, directed across the axis of the cartilage ; from which he inferred that these cartilages were naturally made up of such transverse lamellæ : but the point does not appear to have been further investigated.

Structure of the laryngeal and nasal cartilages.

The description given of the microscopic characters of the costal cartilages will apply with little variation to the ensiform cartilage of the sternum, to the cartilages of the larynx and windpipe, except the epiglottis and cornicula laryngis, and to the cartilages of the nose. With the exception of the last, these resemble the rib cartilages also in their tendency to ossify.

Yellow cartilages.

The epiglottis and cornicula, the cartilages of the ear and of the eyelid, differ so much from the foregoing, both in intimate structure and outward characters, that they have been included in a class apart, under the name of the "yellow" or "spongy" cartilages. These are opaque and yellow, are more flexible than the ordinary cartilages, and have little tendency to ossify. They are made up of cells and a matrix, but the latter is everywhere pervaded with fibres. (Fig. 31'.) These fibres resist the action of acetic acid ; they are in most parts

Fig. 31'.†

* Mem. de l'Acad. des Sc. de Paris, 1748.

† Section of the epiglottis magnified 380 diameters. (After Baly in Müller's Physiology, page 391.)

short, straight, and confusedly intersecting each other in all directions, like the filaments in a piece of felt; in such parts the matrix has a rough indistinctly granular look. Here and there the fibres are longer and more fasciculated, but still interlace at short distances. In thin sections the cells readily drop out from the matrix, leaving empty the cavities which they occupied.

The characters of the temporary cartilages will be given in the account of the formation of bone.

No nerves have been traced into any of the cartilages, and they are known to be destitute of sensibility. Absence of nerves.

In the healthy state, no blood-vessels penetrate the articular cartilages. Whatever nutrient fluid they require seems to be derived from the vessels of adjoining textures, especially the bone, and to be conveyed through the tissue by imbibition. In the embryo a layer of vessels is prolonged some way over the surface, underneath the synovial membrane; but, as development proceeds, these subsynovial vessels retire towards the circumference of the cartilage, and eventually form a narrow vascular border round it, which has been named the circulus articuli vasculosus. Vessels and nutrition.

When the tissue exists in thicker masses, as in the cartilages of the ribs, canals are excavated in its substance, along which vessels are conducted to supply nourishment to the part too distant to receive it from the vessels of the perichondrium. But these canals are few and wide apart, and the vessels do not pass beyond them to ramify in the intermediate mass, which is accordingly quite extra-vascular. It must be further remembered respecting these vascular canals, that many of them lead to spots where the cartilage is undergoing ossification, and convey vessels to supply the bony deposits.

Ordinary permanent cartilage contains about three-fifths of its weight of water, and becomes transparent by drying. By boiling it in water for 15 or 20 hours it is resolved into chondrin. This is a substance said to gelatinise on cooling, although it may be doubted whether the congelation is not in reality owing to an admixture of gelatine derived from fibrous tissue not duly separated from the cartilage. Like gelatine, chondrin is thrown down from its solutions by tannic acid, alcohol, ether, creosote, and corrosive sublimate, and not by prussiate of potash. It differs from gelatine in being precipitated by the mineral and other acids, the acetic not excepted; also by alum, sulphate of alumina, persulphate of iron and Chemical composition.

acetate of lead ; the precipitates being soluble in an excess of the respective precipitants. The temporary cartilages are resolved into a matter which has the chemical reactions of chondrin, but does not gelatinise. The yellow cartilages, by several days' boiling, yield a small quantity of the same variety of chondrin. Cartilage affords by incineration a certain amount of mineral ingredients ; 3·4 per cent. of ashes were obtained from costal cartilages by Frommherz and Gugert, and 100 parts of these ashes were found to consist of

Carbonate of soda	35·07
Sulphate of soda	24·24
Chloride of sodium	8·23
Phosphate of soda	0·92
Sulphate of potash	1·20
Carbonate of lime	18·37
Phosphate of lime	4·06
Phosphate of magnesia	6·91
Oxide of iron, and loss	1·00

Development.

The process by which cartilage is developed is very imperfectly known.

Nucleated cells are seen in a transparent intercellular substance or blastema, very sparing in quantity and much softer than the future matrix. The cells augment in number and enlarge in size, though in some cases, as will be explained, their cavity is subsequently narrowed. Their multiplication may take place by endogenous generation ; that is, by the production of young cells within those already existing, whilst the parietes of the old ones become blended with the matrix ; or they may increase in number by the independent formation of new cells in the intervals of the old. Schwann considers the latter to be the common mode, but his opinion is not that most generally adopted. He states that new cells arise in the intercellular substance near the surface of the cartilage and between the more recent of those already formed (see fig. 5′, [3]), and that free nuclei are first generated in the mass and then the cell-wall formed round them (fig. 5′, [1] and [2]). The intercellular substance increases in quantity and acquires greater consistency, and its growth contributes more to that of the cartilage than does the multiplication of the cells. Its increase may take place by the cell-walls becoming thickened and then more or less blended with the surrounding mass as already described in the case of the branchial cartilage of the fish (fig. 6′), or new matter may be deposited between the cells and independently of them ; or both processes may be combined. As already stated, the matrix in many parts subsequently becomes fibrous, affording an example of the production of fibres in amorphous matter without the intervention of cells or nuclei.

Vital processes.

The vital changes which occur in cartilage take place very slowly. Its mode of nutrition has been already referred to ;

it is subject to absorption, and when a portion is absorbed in disease or removed by the knife, it is not regenerated. Also, when fractured, as sometimes happens with the rib-cartilages, there is no re-union by cartilaginous matter, but the broken surfaces become connected, especially at their circumference, by fibrous or dense areolar tissue, often by a bony clasp.

FIBRO-CARTILAGE.

This is a substance consisting of a mixture of the fibrous and cartilaginous tissues, and so far partaking of the qualities of both. Like cartilage, it possesses firmness and elasticity, but these properties are united with a much greater degree of flexibility and toughness. It presents itself under various forms, which may be enumerated under the following heads :— *Its general nature and properties.* *Varieties.*

1. *Interarticular* fibro-cartilages. These are interposed between the moving surfaces of bones, or rather of articular cartilages, in several of the joints. They serve to maintain the apposition of the opposed surfaces in their various motions, to give ease to the gliding movement, and to moderate the effects of great pressure. In the joint of the lower jaw and in that of the clavicle they have the form of round or oval plates, growing thinner towards their centre ; in the knee-joint they are curved in form of a sickle, and thinned away towards their concave free edge. In all cases their surfaces are free, while they are fixed by synovial or fibrous membrane at their circumference or extremities. The synovial membrane of the joint, or at least its epithelial coat, is prolonged for a short distance upon these fibro-cartilages, from their attached margin. *Interarticular.*

2. The articular cavities of bones are sometimes deepened and extended by means of a rim or border of fibro-cartilage. A good example of one of these *circumferential* or *marginal* fibro-cartilages is seen in the hip-joint, attached round the lip of the cotyloid cavity. *Circumferential or marginal.*

3. *Connecting* fibro-cartilages are such as pass between the adjacent surfaces of bones in joints which do not admit of gliding motion, as at the symphysis of the pubes and between the bodies of the vertebræ. They have the general form of disks, and are composed of concentric rings of fibrous tissue with cartilage interposed ; the former predominating at the circumference, the latter increasing towards the *Connecting.*

centre. The modifications which they present in particular instances are described in the special anatomy of the joints.

4. The bony grooves in which tendons of muscles glide are lined with a thin layer of fibro-cartilage. Small nodules of this tissue (sesamoid fibro-cartilages) may also be developed in the substance of tendons, of which there is an example in the tendon of the tibialis posticus, where it passes beneath the head of the astragalus. Lastly, fibro-cartilage is sometimes connected with muscular tissue, and gives attachment to muscular fibres, like that which is known to exist at the orifices of the heart.

Microscopic characters.

Fibro-cartilage appears under the microscope to be made up of bundles of fibres, like those of ordinary ligament, with cartilage-cells intermixed; but the proportion of the two elements differs much in the different instances above enumerated. In general the fibrous tissue very greatly predominates, and in some cases, as in the interarticular laminæ of the knee-joint, it constitutes almost the entire structure. In the intervertebral disks the cartilage corpuscles are abundant towards the centre of the mass where the cartilaginous tissue prevails, and the substance is softer.

Chemical composition.

In chemical composition this texture agrees most with ligament, yielding gelatin when boiled.

Vessels and vital processes.

Its blood-vessels are very few, and, according to Mr. Toynbee,* are confined to the parts that are fibrous. Its vital changes are slow; it is subject to absorption, but much less readily so than bone; hence it is no uncommon thing to find the intervertebral disks entire when the adjacent bodies of the vertebræ have been destroyed by disease. It has not much tendency to ossify.

Development.

Little is known concerning the mode of development of fibro-cartilage. Mr. Toynbee concludes from his researches that the cartilaginous element is relatively more abundant at early periods.

BONE, OR OSSEOUS TISSUE.

Uses.

The bones are the principal organs of support, and the passive instruments of locomotion. Connected together in the skeleton, they form a framework of hard material, which affords attachment to the soft parts, maintains them in their due position, and shelters such as are of delicate structure,

* Phil. Trans. 1841.

giving stability to the whole fabric, and preserving its shape; and the different pieces of the skeleton, being jointed moveably together, serve also as levers for executing the movements of the body.

In their outward forms the bones present much diversity, but have been reduced by anatomists to the following classes:—1. Long or cylindrical, such as the chief bones of the limbs. These consist of a body or shaft, cylindrical or more frequently angular in shape, and two ends, or heads as they are often called, which are usually much thicker than the shaft. The heads, or ends, have smooth surfaces for articulation with neighbouring bones. The shaft is hollow and filled with marrow, by which sufficient magnitude and strength are attained without undue increase of weight. 2. Tabular or flat bones, like the scapula, the ilium, the ribs, the lower jaw, and the bones forming the roof and sides of the scull. Many of these contribute to form the walls of cavities. 3. Short bones, often also called round bones, though most of them rather are angular; the wrist and tarsus afford examples of these. 4. Irregular or mixed bones, which would, perhaps, be better named "complex;" such as cannot be entirely referred to any of the foregoing classes. These are mostly situated in the median plane, and have a complex but symmetrical figure; the vertebræ may be taken as instances of them. Form and external characters. Classes of Bones. 1. Long or cylindrical. 2. Tabular or flat. 3. Short or round. 4. Mixed or irregular.

The surfaces of bones present various eminences, depressions, and other marks; and, to designate these in descriptive osteology, certain general terms are employed, of which the following are those most commonly in use. Surfaces of Bones.

1. Eminences. To any prominent elevation jutting out from the surface of a bone the term "process" or "apophysis" is applied. It often happens that such a process is originally ossified separately from the rest of the bone, and remains long unconnected with the main body (by osseous union at least); in this condition it is named an "epiphysis." In many bones, considerable portions at the extremities or most prominent parts are originally ossified separately as epiphyses. This is the case with the ends of the long bones, and in this instance the shaft is named the "diaphysis." Eminences. A process or Apophysis. Epiphysis. Diaphysis.

Processes or apophyses are further designated according to their different forms. A slender, sharp, or pointed eminence is named a "spine" or "spinous process;" a tubercle, on the other hand, is a blunt prominence; a "tuberosity" Spine. Tubercle.

Tuberosity. Crest. (tuber) is broader in proportion to its elevation, and has a rough uneven surface. The term "crest" is usually applied to the prominent border of a bone, or to an elevation running some way along its surface; but the latter is more commonly denominated a "line" or "ridge." A "head" (caput, capitulum, or capitellum) is a rounded process, supported on a narrower part named its neck (cervix). A "condyle" has been defined to be an eminence bearing a flattened articular surface; but this term has been very variously applied by anatomists both ancient and modern.

Line. Head and cervix. Condyle.

Cavities and depressions. 2. Cavities and depressions of bones. An aperture or perforation in the substance of a bone is named a "foramen." A passage or perforation often runs for some way in the bone, and then it is termed a "canal" or "meatus." On the other hand, it may assume the form of a "fissure," and is named accordingly. A "fossa" is an open excavation or depression on the surface of a bone, or of a part of the skeleton formed by several bones. A fossa may form part of a joint, and be adapted to receive the prominent part of a neighbouring bone; it is then said to be "glenoid," when shallow: but a deep excavation, of which the socket for the head of the thigh-bone is an example, is named a "cotyloid" cavity. The meaning of the terms "notch" (incisura) and "groove" or "furrow" (sulcus) is sufficiently plain. "Sinus" and "antrum" are names applied to certain large cavities situated within the bones of the head and opening into the nose.

Fissure. Fossa. Glenoid and cotyloid cavities. Sinus and antrum.

Bony tissue. In the recent state, bones are covered with periosteum and filled with marrow: they also receive vessels for their nutrition. These soft structures will be noticed in due time, but we shall in the first place consider the proper bony substance.

Physical properties. Bone has a white colour, with a pink and slightly bluish tint in the living body. Its hardness is well known, but it also possesses a certain degree of toughness and elasticity; the last property is peculiarly well marked in the ribs. Its specific gravity is from 1·87 to 1·97.

Chemical composition. It consists of an earthy and an animal part, intimately combined together; the former gives hardness and rigidity, the latter tenacity to the osseous tissue.

Earthy part. The earthy part may be obtained separate by calcination. When bones are burned in an open fire, they first become quite black, like a piece of burnt wood, from the charring of their animal matter; but if the fire be continued with free

access of air, this matter is entirely consumed, and they are reduced to a white, brittle, chalk-like substance, still preserving their original shape, but with the loss of about a third of their weight. The earthy constituent, therefore, amounts to about two-thirds of the weight of the bone. It consists principally of phosphate of lime, with about a fifth part of carbonate of lime, and much smaller proportions of fluoride of calcium, chloride of sodium, and magnesian salts.

Animal part.

The animal constituent may be freed from the earth, by steeping a bone in diluted nitric or hydrochloric acid. By this process the salts of lime are dissolved out, and a tough, flexible substance remains, which, like the earthy part, retains the perfect figure of the original bone in its minutest details; so that the two are evidently combined in the most intimate manner. The animal part is often named the cartilage of bone, but improperly, for it differs entirely from cartilage in structure, as well as in physical properties and chemical constitution. It is much softer and much more flexible, and by boiling it is almost wholly resolved into gelatin. It may accordingly be extracted from bones, in form of a jelly, by boiling them for a considerable time, especially under high pressure.

Proportions of earthy and animal matter in different circumstances.

The earthy or saline matter of bone, as already stated, constitutes about two-thirds or 66·7 per cent., and the animal part one-third or 33·3 per cent.; but the bones of children, which are known to be less rigid than those of adults, yield more animal matter, and those of aged persons more earth. A difference, too, has been observed in different bones of the skeleton. Thus, according to Dr. Rees, whose statements are confirmed by the elaborate analyses of Von Bibra, the bones of the head and of the limbs contain more earth than those of the trunk. It still, however, remains to be determined whether these differences apply to the constitution of the bony matter strictly so called, or whether they may not be occasioned by the different proportions of membranous substance and other soft tissues contained in the minute cavities of bones, and not so perfectly separable from them as to leave a pure material for analysis.

Earthy constituents more fully considered.

Subjoined are the statements of two analyses. The one, by Berzelius, is well known; the other, which nearly agrees with it, was performed by Mr. Middleton, in the laboratory of University College.*

	Berzelius.		Middleton.
Animal matter	33·30	—	33·43
Phosphate of lime	51·04	—	51·11
Carbonate of lime	11·30	—	10·31
Fluoride of calcium	2·00	—	1·99

* Philosophical Magazine, vol. xxv. p. 18.

[redacted]

	Berzelius.		Middleton.
Magnesia, wholly or partially in the state of phosphate . . .	1·16	—	1·67
Soda and chloride of sodium . . .	1·20	—	1·68

The phosphate of lime is peculiar, and passes in chemistry under the name of the "bone-earth phosphate." It is a tribasic phosphate, consisting probably of 8 equivalents of lime and 1 of water, with 3 eq. of phosphoric acid. The carbonate is said by Denis to exist in larger proportion in the bones of children. The fluoride of calcium is found in larger quantity in fossil than in recent bones,—indeed, its presence in the latter was lately denied altogether; but since then, the original statements of Morichini and of Berzelius, to the effect that it exists in recent as well as fossil bones, have been satisfactorily confirmed.*

Structure of Bone.

Compact and spongy.

On sawing up a bone, it will be seen that it is in some parts dense and close in texture, appearing like ivory ; in others open and reticular : and anatomists accordingly distinguish two forms of osseous tissue, viz. the *compact*, and the *spongy* or *cancellated*. On closer examination, however, especially with the aid of a magnifying glass, it will be found that the bony matter is everywhere porous in a greater or less degree, and that the difference between the two varieties of tissue depends on the different amount of solid matter compared with the size and number of the open spaces in each : the cavities being very small in the compact parts of the bone, with much dense matter between them ; whilst in the cancellated texture the spaces are large, and the intervening bony partitions thin and slender. There is, accordingly, no abrupt limit between the two,—they pass into one another by degrees, the cavities of the compact tissue widening out, and the reticulations of the cancellated becoming closer as they approach the parts where the transition takes place.

Arrangement in different bones.

In all bones, the part next the surface consists of compact substance, which forms an outer shell or crust, whilst the spongy texture is contained within. In a long bone, the large round ends are made up of spongy tissue, with only a thin coating of compact substance ; in the hollow shaft, on the other hand, the spongy texture is scanty, and the sides are chiefly formed of compact bone, which increases in thickness from the extremities towards the middle, at which point usually the girth of the bone is least, whilst the strain on it is there greatest. In tabular bones, such as those of the

* By Dr. Daubeny, Phil. Mag. vol. xxv. p. 122 ; and Mr. Middleton, loc. cit.

skull, the compact tissue forms two plates, or tables as they are called, inclosing between them the spongy texture, which in such bones is usually named *diploe*. The short bones, like the ends of the long, are spongy throughout, save at their surface, where there is a thin crust of compact substance. In the irregular or mixed bones, the two substances have the same general relation to each other ; but the relative amount of each in different parts, as well as their special arrangement in particular instances, is very various.

Cancellated texture.

On close inspection, the cancellated texture is seen to be formed of slender bars or spicula of bone and thin lamellæ, which meet together and join in a reticular manner, producing an open structure which has been compared to lattice-work (*cancelli*), and hence the name usually applied to it. In this way considerable strength is attained without undue weight, and it may usually be observed that the strongest laminæ run through the structure in those directions in which the bone has naturally to sustain the greatest pressure. The open spaces or areolæ of the bony net-work communicate freely together; in the fresh state they contain marrow or blood-vessels, and give support to these tender structures.

Compact tissue.

The compact tissue is also full of holes ; these, which are very small, are best seen by breaking across the shaft of a long bone near its middle, and examining it with a common magnifying glass. Numerous little round apertures (fig. 32′, A) may then be seen on the broken surface, which are the openings of short longitudinal passages running in the compact substance, and named the Haversian canals, after Clopton Havers, an English physician and writer of the seventeenth century, who more especially called attention to them. Blood-vessels run in these canals, and the widest of them also contain marrow. They are from $\frac{1}{1000}$th to $\frac{1}{200}$th of an inch in diameter : I have measured some which were no more than $\frac{1}{2000}$th, but these are rare ; the medium size is about $\frac{1}{500}$th. The widest are those nearest the medullary cavity, and they are much smaller towards the circumference of the bone. They are quite short, as may be seen in a longitudinal section, and somewhat crooked or oblique at their ends, where they freely open into one another, their oblique communications connecting them both longitudinally and laterally. Those also which are next the circumference of the bone, open by minute pores on its external surface, and the innermost ones open widely

Canals of Havers.

into the medullary cavity; so that these short channels collectively form a sort of irregular net-work of tubes running

Fig. 32'.*

through the compact tissue, in which the vessels of that tissue are lodged, and through the medium of which these vessels communicate together, not only along the length of the bone, but from its surface to the interior, through the thickness of the shaft. The canals of the compact tissue in the other classes of bones have the same general characters, and for the most part run parallel to the surface.

Lamellar structure of bone.

On viewing a thin transverse section of a long bone with

* A. Transverse section of a bone (ulna) deprived of its earth by acid. The openings of the Haversian canals seen. Natural size. A small portion is shaded to indicate the part magnified in fig. B.

B. Part of the section A magnified 20 diameters. The lines indicating the concentric lamellæ are seen, and among them the corpuscles or lacunæ appear as little dark specks.

a microscope of moderate power, especially after the earthy part has been removed by acid (fig. 32′, B), the opening of each Haversian canal appears to be surrounded by a series of concentric rings. This appearance is occasioned by the transverse sections of concentric lamellæ which surround the canals. The rings are not all complete, for here and there one may be seen ending between two others. In some of the sets the rings are nearly circular, in others oval,—differences which seem mostly to depend on the direction in which the canal happens to be cut: the aperture, too, may be in the centre, or more or less to one side, and in the latter case the rings are usually narrower and closer together on the side towards which the aperture deviates. Again, some of the apertures are much lengthened or angular in shape, and the lamellæ surrounding them have a corresponding disposition. Besides the lamellæ surrounding the Haversian canals, there are others disposed conformably with the circumference of the bone (fig. 32′, B, *a*), and which may therefore be said to be concentric with the medullary canal; some of these are near the surface of the bone, others run between the Haversian sets, by which they are interrupted in many places. Lastly, in various parts of the section, lines are seen which indicate lamellæ, differing in direction from both of the above-mentioned orders. As to the circumferential laminæ Messrs. Tomes and De Morgan state that they are by no means so common as is generally supposed; further, that they are most conspicuous in bones of full growth, in which, consequently, nutritive changes proceed slowly; and that their presence may be made the means of determining, within certain limits, the age at which a bone has arrived. These authors observe, that in young and rapidly growing bones the laminæ are frequently seen to have an undulating direction, which they consider as a sign that the tissue is undergoing rapid nutritive changes.

The appearance in a longitudinal section of the bone is in harmony with the account above given: the sections of the lamellæ are seen as straight and parallel lines, running in the longitudinal direction of the bone, except when the section happens to have passed directly or slantingly across a canal; for wherever this occurs there is seen, as in a transverse section, a series of rings, generally oval and much lengthened on account of the obliquity of the section.

The cancellated texture has essentially the same lamellar

structure. The slender bony walls of its little cavities or areolæ are made up of superimposed lamellæ, like those of the Haversian canals (fig. 32′, B, b), only they have fewer lamellæ in proportion to the width of the cavities which they surround; and, indeed, the relative amount of solid matter and open space constitutes, as already said, the only difference between the two forms of bony tissue; the intimate structure of the solid substance and the manner of its disposition round the cavities being essentially the same in both.

Haversian spaces.

Besides the openings of Haversian canals as above described, a transverse section of the compact bone now and then presents vacuities or spaces formed by absorption of the tissue. These are named "Haversian spaces" by Tomes and De Morgan, who first showed that they occur not only in growing bone but at all periods of life. In their primitive condition these cavities are characterised by an irregular or jagged outline, and their formation by absorption is further indicated by their encroaching on the adjacent groups of concentric lamellæ, which have been, as it were, eaten away to a greater or less extent to give place to the new cavity. In another stage the spaces in question are lined by new-formed lamellæ, which may as yet be confined to the peripheral part of the vacuity, or may fill it up in a concentric series, leaving a Haversian aperture in the middle, and in fact constituting a system of concentric Haversian lamellæ, interpolated or intruded among those previously existing. The concentric lamellæ, which thus come to occupy a greater or less extent of the area of the cavity, are of course bounded exteriorly by segments of adjoining Haversian lamellæ, which have been more or less cut in upon in the excavation of the space. It has been further observed by Tomes and De Morgan, that vacuities may sometimes be seen which are being filled up at one part by the deposition of lamellæ, whilst they are extending themselves by absorption at another. The Haversian spaces are most numerous in young and growing bones; but, as already stated, they occur also after growth is completed. Their origin and changes will be better understood after the reader has perused the account of the growth and development of bone, to which head indeed the subject more properly belongs, although it has seemed expedient to introduce it here.

In many of the osseous laminæ it is easy to recognise, with a high power of the microscope, an outer, apparently granular, and an inner apparently homogeneous layer.

All over the section numerous little dark specks are seen among the lamellæ. These were named the "osseous corpuscles;" but as it is now known that they are in reality minute cavities existing in the bony substance, the name of "lacunæ" has since been more fittingly applied to them. To see the lacunæ properly, however, sections of unsoftened bones must be prepared and ground very thin, and a magnifying power of from 200 to 300 must be employed. Such a section, viewed with transmitted light, has the appearance represented in fig. 33′. The openings of the Haversian Lacunæ or corpuscles.

Fig. 33′.*

canals are seen with their encircling lamellæ, and among these the corpuscles or lacunæ, which are mostly ranged in a corresponding order, appear as black or very dark brown and nearly opaque, oblong spots, with fine dark lines extending from them and causing them to look not unlike

* Transverse section of compact tissue (of humerus) magnified about 150 diameters. Three of the Haversian canals are seen, with their concentric rings; also the corpuscles or lacunæ, with the canaliculi extending from them across the direction of the lamellæ. The Haversian apertures had got filled with débris in grinding down the section, and therefore appear black in the figure, which represents the object as viewed with transmitted light.

little black insects; but when the same section is seen against a dark ground, with the light falling on it (as we usually view an opaque object), the little bodies and lines appear quite white, like figures drawn with chalk on a slate, and the intermediate substance, being transparent, now appears dark.

Canaliculi. The lacunæ, as already stated, are minute recesses in the bone, and the lines extending from them are fine pores or tubes named "canaliculi," which issue from their cavity. They present some variety of figure, but in such a section as that represented, for the most part appear irregularly fusiform, and lie nearly in the same direction as the lamellæ between which they are situated; or, to speak more correctly, the little cavities are flattened and extended conformably with the lamellæ; for when the bone is cut longitudinally, their sections still appear fusiform and lengthened out in the direction of the lamellæ. The canaliculi, on the other hand, pass across the lamellæ, and they communicate with those proceeding from the next range of lacunæ, so as to connect the little cavities with each other; and, thus, since the canaliculi of the most central range open into the Haversian canal, a system of continuous passages is established by these tubules and their lacunæ, along which fluids may be conducted from the Haversian canal through its series of surrounding lamellæ; indeed it seems probable that the chief purpose of these minute passages is to convey nutrient fluid from the vascular Haversian canals through the mass of hard bone which lies around and between them. In like manner the canaliculi open into the great medullary canal, and into the cavities of the cancellated texture; for in the thin bony parietes of these cavities lacunæ are contained; they exist indeed in all parts of the bony tissue. Virchow conceives that each lacuna is occupied by a ramified nucleated cell, the walls of which are exactly applied to the inside of the bony cavity, whilst the branches or tubular prolongations of the cell line the canaliculi and anastomose with intra-canalicular branches of similar cells which occupy neighbouring lacunæ. He considers that these cells are homologous with the branched elastic fibres (formerly called nuclear fibres) of the areolar and fibrous tissues,—fibres which, with Donders and others, he regards as formed by the ramification and anastomosis of cells,—whilst the calcified osseous tissue is supposed to represent the mass of the areolar or fibrous

tissue through which these branched fibre-cells are distributed. Virchow ascribes to the intra-lacunar cells and their ramifications the office of conveying nutritious fluid through the bony tissue. He has succeeded in separating them from the surrounding substance by prolonged maceration of decalcified bone in hydrochloric acid or in alkalies.

Structure of the lamellæ.

To return to the lamellæ. With a little pains thin films may be peeled off in a longitudinal direction from a piece of bone that has been softened in acid. These for the most part consist of several laminæ, as may be seen at the edge, where the different layers are usually torn unequally and some extend farther than others. Examined in this way, under the microscope, the lamellæ are seen to be perforated with fine apertures placed at very short distances apart. These apertures were described by Deutsch,* but they have not much attracted the notice of succeeding observers; they appear to me to be the transverse sections of the canaliculi already described, and their relative distance and position accord sufficiently with this explanation. According to this view, therefore, the canaliculi might (in a certain sense) be conceived to result from the apposition of a series of perforated plates, the apertures of each plate corresponding to those of the plates contiguous with it; in short, they might be compared to holes bored to some depth in a straight or crooked direction through the leaves of a book, in which case it is plain that the perforations of the adjoining leaves would correspond; it being always understood however that the passages thus formed are lined or bounded by membranous parietes.

Fibro-reticular.

But the lamellæ have a further structure. To see this the thinnest part of a detached shred or film must be examined, as shown in fig. 34′; it will then appear plainly that they are made up of transparent fibres, decussating each other in form of an exceedingly fine net-work. The fibres intersect obliquely, and they seem to coalesce at the points of intersection, for they cannot be teased out from one another; but at the torn edge of the lamella they may often be seen separate for a little way, standing out like the threads of a fringe. Most generally they are straight, as represented in the figure; but they are not always so, for in some parts they assume a curvilinear direction.

* De Penitiori Ossium Structurâ. Wratisl. 1834, p. 17, fig. 6.

Acetic or hydrochloric acid causes these fibres to swell up and become indistinct, like the white fibres of areolar and fibrous tissue; care must therefore be taken, in their examination, that the remains of the decalcifying acid be removed from the tissue, by maceration in water or in solution of an alkaline carbonate. Moreover, the fibro-reticular structure is not equally distinct in all parts where its presence is recognisable; for in some places it is less decidedly marked, as if the fibrillation were incompletely developed—resembling in this respect the areolar and fibrous tissues.

Fig. 34'.*

Perforating fibres.

In many instances the lamellæ are perforated by fibres, or rather bundles of fibres, which pass through them in a perpendicular, or more or less oblique direction, and, as it were, bolt them together. These *perforating fibres* may be seen, with the aid of the microscope, in a thin transverse slice of a decalcified cylindrical or cranial bone, on pulling asunder the sections of the lamellæ. In this way some lamellæ will generally be observed with fibrous processes attached to them, of various lengths, and usually tapering and pointed at their free extremities, but sometimes abruptly truncated. These fibres have obviously been drawn out from the adjacent lamellæ, through several of which they must have penetrated. Sometimes, indeed, indications of perforations may be recognised in the part of the section of bone from which the fibres have been pulled out. The processes in question are thus, so to speak, viewed in profile; but they may frequently also be seen on the flat surface of detached lamellæ, projecting like nails driven perpendicularly or slantingly through a board; whilst other lamellæ present obvious apertures of considerable size, through which the perforating fibres had passed.

The structure here referred to is not to be confounded with the

* Thin layer peeled off from a softened bone, as it appears under a magnifying power of 400. The figure, which is intended to represent the reticular structure of a lamella, gives a better idea of the object when held rather farther off than usual from the eye.

"tubes" observed by Tomes and De Morgan in certain situations, and described as penetrating more or less obliquely from the surface towards the interior of the bone.* The perforating fibres are not tubular but solid; they may be found, after decalcification, in parts where no tubes were previously discoverable, and they are far more generally distributed in the bony tissue.

It thus appears that the animal basis of bone is made up of superimposed lamellæ, and that these lamellæ are composed of fine reticular fibres. This I believe to be the prevalent structure; but two other forms of tissue are also met with in decalcified bone, viz.

1. Flattened cells, cohering by their edges in layers, with more or less of an amorphous or finely granular matrix. So far as I have been able to observe, these strata of cells principally occur at or near the surface of the compact tissue of the shaft in cylindrical bones, and at or immediately outside the circumference of many of the systems of concentric Haversian lamellæ, in these as well as in other bones.

2. True Cartilage.—Ossified cartilage is found on the articular ends of adult bones, lying underneath the natural cartilage of the joint, both in the moveable articulations and in symphyses, and is in fact the deeper part of the cartilage, which has been encroached upon by the calcifying process. The animal basis is here, however, of a totally different nature from that of the bone beneath; for, on extracting the earthy matter by means of an acid, the tissue which remains has all the characters of cartilage. Cartilage also forms the animal basis of the bone in a few other parts of the skeleton, but only in very limited portions; according to Tomes and De Morgan it occurs in the petrous part of the temporal bone.

As to the mode in which the earthy particles are connected with the animal texture, we know that the combination is very intimate, but the manner in which it is effected is not understood.

Periosteum.

The periosteum, as already stated, is a fibrous membrane which covers the bones externally. It adheres to them very firmly, and invests every part of their surface, except where they are covered with cartilage or connected to other bones by fibro-cartilage. According to Kölliker it is composed of two distinct layers; the outer, consisting of areolar (white) fibres, and containing occasional fat-cells, is the means of supporting numerous blood-vessels destined for the bone,

* Phil. Trans. 1853, p. 116.

which ramify in the membrane, and at length send their minute branches into the Haversian canals of the compact substance, accompanied by processes of filamentous tissue derived from, or at least continuous with, the periosteum. The inner layer is made up of elastic fibres; and frequently presents the appearance of several distinct strata of "elastic membrane." Fine nervous filaments spread out in the periosteum; they are chiefly associated with the arteries, and for the most part destined for the subjacent bone; but some are for the membrane itself.

The chief use of this membrane is evidently to support the vessels going to the bone, and afford them a bed in which they may subdivide into fine branches, and so enter the dense tissue at numerous points. Hence, when the periosteum is stripped off at any part, there is great risk that the denuded portion of the bone will die and exfoliate. The periosteum also contributes to give firmer hold to the tendons and ligaments where they are fixed to bones; indeed, these fibrous structures become continuous and incorporated with it at their attachment.

Marrow. The marrow (medulla ossium) is lodged in the interior of the bones; it fills up the hollow shaft of long bones and occupies the cavities of the cancellated structure; it extends also into the Haversian canals—at least into the larger ones—along with the vessels. Like ordinary adipose tissue, it consists of vesicles containing fat, with blood-vessels distributed to them. A fine layer of a highly vascular areolar tissue lines the medullary canal, as well as the smaller cavities which contain marrow; this has been named the medullary membrane, internal periosteum, or endosteum; but it cannot be detached as a continuous membrane. Its vessels partly supply the contiguous osseous substance, and partly proceed to the clusters of adipose vesicles, among which there is but very little areolar tissue, in consequence perhaps of their being contained and supported by bone.

The marrow differs considerably in different situations. Within the shaft of the long bones it is of a yellow colour, and contains, in 100 parts, 96 of fat, 1 of areolar tissue, and 3 of water. In short bones, and in the cancellated ends of long bones, but especially in the cranial diploe, the bodies of the vertebræ, the sternum, and the ribs, it is red or reddish in colour, of more fluid consistence, and with very few fat cells. That from the diploe consists of 75 parts of water and 25 of solid matters, which are chiefly albumen, fibrin, extractive and salts, with mere traces of fat. While, however, the fat-cells are scanty in the red-coloured marrow, it contains minute, roundish nucleated cells—the proper marrow-cells of Kölliker. These, which include no fat, correspond in character with the cells found in the articular ends of long bones affected with hyperæmia; they occur normally in the cranial

bones, vertebræ, and sternum, and in variable number in the scapula, the innominate, and facial bones.

The marrow serves the same general purposes in the economy as ordinary fat. Placed within the bones, which are made hollow for the sake of lightness, it serves as a light and soft material to fill up their cavities and support their vessels. In birds, for the sake of still further lightening their skeleton, the larger bones, instead of being filled with marrow, contain air, which passes into them from the lungs by openings at their extremities. Even in man there are certain hollow bones of the cranium and face which are naturally filled with air. The cavities of these bones are named sinuses; they open into the adjoining air-passages, and are lined with a prolongation of the mucous membrane, underneath which is a thin periosteum.

The bones do not at first contain marrow; in the fœtus their cavities are filled with a transparent reddish fluid, like bloody serum, only more consistent and tenacious. In dropsical subjects also, the marrow, like the rest of the fat, is consumed to a greater or less extent, its place being occupied by a serous fluid.

Blood-vessels; their relation to the osseous substance.

The bones are well supplied with blood-vessels. A network of periosteal vessels covers their outward surface, others penetrate to the cavities of the spongy part and the medullary canal, on the sides of which they ramify, and fine vessels, deprived of their muscular coat, run through all parts of the compact tissue in the Haversian canals. The sides of these internal cavities and canals make up together a large extent of inward surface on which vessels are spread. The nutritious fluid conveyed by these vessels no doubt escapes through their coats and permeates the surrounding dense bone interposed between the vascular canals; and it seems highly probable that the system of lacunæ and communicating canaliculi, already described, is a provision for conducting the exuded fluid through the hard mass. When a bone is macerated, its vessels and membranes are destroyed, whilst the intermediate true bony matter, being of an incorruptible and persistent nature, remains; a process which, for obvious reasons, cannot be effected with the soft tissues of the body.

How seen.

The vessels of bone may be recognised while it is yet fresh by the colour of the blood contained in them; but they are rendered much more conspicuous by injecting a limb with size and vermilion, depriving the bones of their earth by means of an acid, and then drying them and putting them into oil of turpentine, by which process the osseous tissue is rendered transparent, whilst the injected matter in the vessels retains its red colour and opacity.

Vessels of compact substance.

Numberless small vessels derived from the periosteum, as already mentioned, pass along the Haversian canals in the

compact substance. These are both arterial and venous, but, according to Todd and Bowman, the two kinds of vessels occupy distinct passages ; and the veins, which are the larger, present, at irregular intervals, pouch-like dilatations calculated to serve as reservoirs for the blood, and to delay its escape from the tissue. Arteries, of larger size but fewer in number, proceed to the cancellated texture. In the long bones numerous apertures may be seen at the ends, near the articular surfaces ; some of these give passage to the arteries referred to, but the greater number, as well as the larger of them, are for the veins of the cancellated texture, which run separately from the arteries. Lastly, a considerable artery goes to the marrow in the central part of the bone ; in the long bones this medullary artery, often, but improperly, called "the nutritious artery," passes into the medullary canal, near the middle of the shaft, by a hole running obliquely through the compact substance. The vessel, which is accompanied by one or two veins, then sends branches upwards and downwards to the marrow and medullary membrane in the central cavity and adjoining the Haversian canals. Its ramifications anastomose with the arteries of the compact and cancellated structure ; indeed, there is a free communication between the finest branches of all the vessels which proceed to the bone, and there is no strictly defined limit between the parts supplied by each. In the thigh-bone there are two medullary arteries entering at different points.

Of cancellated.

Medullary vessels.

Veins of cancelli.

The veins of the cancellated texture are peculiar and deserve special notice. They are large and numerous, and run separately from the arteries. Their arrangement is best known in the bones of the skull, where, being lodged in the diploe or spongy texture between the outer and inner compact tables, they have received the name of the diploic veins. They run in canals formed in the cancellated structure, the sides of which are constructed of a thin lamella of bone, perforated here and there for the admission of branches from the adjoining cancelli. The veins, being thus inclosed and supported by the hard structure, have exceedingly thin coats. They issue from the bone by special apertures of large size. A similar arrangement is seen in the bodies of the vertebræ, from whence the veins come out by large openings on the posterior surface.

Lymphatics.

The lymphatics of the bones are but little known ; still, there is evidence of their existence, for, independently of

the authority of Mascagni (which is of less value in this particular instance, inasmuch as he does not state expressly that he injected the vessels which he took for the lymphatics of bone), we have the testimony of Cruikshank, who injected lymphatics coming out of the body of one of the dorsal vertebræ, in the substance of which he also saw them ramifying.*

Fine nerves have been seen passing into the medullary canal of some of the long bones along with the artery, and following its ramifications, but their ultimate distribution is doubtful; and Kölliker describes fine nervous filaments as entering with the other arteries of the bone to the spongy and compact tissue. As far, however, as can be judged from observations on man and experiments on the lower animals, the bones, as well as their investing periosteum, are scarcely if at all sensible in the healthy condition, although they are painfully so when inflamed. Nerves.

Some hold that the same is true of the marrow, or rather the medullary membrane; others, among whom are Duverney and Bichat, affirm, on the contrary, that the medullary tissue is sensible. They state that, on sawing through the bone of a living animal, and irritating the medullary membrane by passing a probe up the cavity or by injecting an acrid fluid, very unequivocal signs of pain will be manifested. Beclard, who affirms the same fact, points out a circumstance which may so far account for the result occasionally turning out differently,—namely, that when the bone happens to be sawn through above the entrance of the medullary artery, the nerves going along with that vessel are divided, and the marrow consequently rendered insensible, as happens with any other sensible part when its nerves are cut.

Formation and growth of bone.—The foundation of the skeleton is laid at a very early period, for among the parts that appear soonest in the embryo, we distinguish the rudiments of the vertebræ and base of the skull, which afterwards form the great median column to which the other parts of the bony fabric are appended. But it is by their outward form and situation only, that the parts representing the future bones are then to be recognised; for at that early period they do not differ materially in substance from the other structures of the embryo, being, like these, made up of granular corpuscles or elementary cells united together by a soft amorphous matter or blastema. Very soon, however, they become cartilaginous, and ossification in due time Early condition of the bones.

* Anatomy of the Absorbing Vessels, 1790, p. 198.

beginning in the cartilage and continuing to spread from one or from several points, the bone is at length completed.

Two modes of ossification.

But while it is true with respect to the bones generally, that their ossification commences in cartilage, it is not so in every instance. The tabular bones, forming the roof of the skull, may be adduced as a decided example to the contrary; in these the ossification goes on in a membranous tissue quite different in its nature from cartilage; * and even in the long bones, in which ossification undoubtedly commences and to a certain extent proceeds in cartilage, it will be afterwards shown that there is much less of the increment of the bone really owing to that mode of ossification than is generally believed. It is necessary, therefore, to distinguish two species or modes of ossification, which for the sake of brevity may be called the *intramembranous* and the *intracartilaginous.*

Intramembranous ossification described.

Ossification in membrane.—The tabular bones of the cranium, as already said, afford an example of this mode of ossification. The base of the skull in the embryo is cartilaginous; but in the roof, that is to say, the part comprehending the parietal, the upper and greater part of the frontal, and a certain portion of the occipital bones, we find (except where there happen to be commencing muscular fibres) only the integuments, the dura mater, and an intermediate membranous layer, which differs from cartilage in its intimate structure as well as in its more obvious characters, and in which the ossification proceeds.

The commencing ossification of the parietal bone, which may be selected as an example, appears to the naked eye in form of a net-work in which the little bars or spicula of bone run in various directions, and meet each other at short distances. By and by the ossified part, becoming extended, gets thicker and closer in texture, especially towards the centre, and the larger bony spicula which now appear, run out in radiating lines to the circumference; the ossification continuing thus to spread and consolidate until the parietal meets the neighbouring bones, with which it is at length united by suture.

The adjoining figure (35′) represents the parietal bone of an embryo sheep, about two inches and a half long, and shows the character of the ossification as it appears

* This fact was pointed out and insisted on by Dr. Nesbitt, who distinguishes the two different modes of ossification, and so far his views are quite correct.—See his human Osteogeny, Lond. 1736.

when the object is magnified about twelve diameters. The bone is formed in membrane as in the human fœtus,

Fig. 35'.*

but a thin plate of cartilage rises up on its inside from the base of the skull. The ossification, however, is decidedly unconnected with the cartilage, and goes on in a membrane lying outside of it. The cartilaginous plate is not represented in the figure, but a dotted line, *a*, *b*, near the top, marks the height to which it reached, and from this it will be seen that the ossification extended beyond the cartilage. In the region of the frontal bone the cartilage does not even

* Parietal bone of an embryo sheep. Size of the embryo, 2½ inches. The small upper figure represents the bone of the natural size, the larger figure is magnified about 12 diameters. The curved line, *a*, *b*, marks the height to which the subjacent cartilaginous lamella extended. A few insulated particles of bone are seen near the circumference, an appearance which is quite common at this stage.

rise so high. In both cases its limit is well defined, and under the microscope it presents a decided contrast to the adjacent membrane.

When further examined with a higher magnifying power, the tissue or membrane in which the ossification is proceeding, appears to be made up of fibres and granular corpuscles, with a soft amorphous or faintly granular uniting matter. The fibres have the characters of the white fibres, or rather fasciculi, of the areolar and the fibrous tissue, and are similarly affected by acetic acid. The corpuscles are for the most part true cells, with an envelope and granular contents ; some about the size of blood-particles, but many of them two or three times larger. In certain parts the fibres, but in most the corpuscles, predominate ; and on the whole the structure might be said to be not unlike that of a fibrous membrane in an early stage of development. The bone, seen by transmitted light, is dark and opaque, and near the growing edge it is decidedly granular.

On observing more closely the bony processes or spicula at the circumference, where they shoot into the membrane (as in fig. 36′), it will be seen, as they are traced into the soft tissue, that they gradually lose their opaque and granular character, indicative of earthy impregnation, and are prolonged a little way into the membrane, in form of bundles of transparent fibres, having all the characters of those of fibrous tissue. These fibres are in some parts closely gathered into thick bundles, but more generally the fasciculi are smaller and irregularly interlaced or reticulated, with corpuscles lying between them ; and we may often observe that where the earthy deposit is advancing to invade the fibres, the recently and as yet imperfectly calcified bone with which they are continuous, presents a similar open and coarsely reticular structure ; though the older, harder, and more opaque part is comparatively solid and compact. The appearance referred to is especially well seen at those places where a cross bridge of bone is being formed between two long spicula ; we may there distinguish the clear soft fibres which have already stretched across the interval, and the dark granular opacity indicating the earthy deposit may be perceived advancing into them and shading off gradually into their pellucid substance without a precise limit.

It thus appears that in the intramembranous ossification the growing bone shoots into the soft tissue, in form of transparent fibres, resembling those of fibrous texture, more

or less intermixed with granular corpuscles, and that these fibres become charged with earthy salts. As to the cells or

Fig. 36'.*

corpuscles, they certainly seem to be in some way involved in the ossification along with the fibres, but I am not able to say what precise share they have in the process. It has been supposed that they eventually form the lacunæ of the bone; but this question will be considered afterwards.

As the bone extends in circumference, it also increases in thickness, the vacuities between the bony spicula become narrowed or disappear, and at a more advanced period the tabular bones of the cranium are tolerably compact towards the centre, although their edges are still formed of slender radiating processes. At this time also numerous furrows are grooved on the surface of the bone in a similar radiating manner, and towards the centre these are continued into

* The growing ends of two bony spicula from the frontal bone of an embryo dog, highly magnified. The surrounding membrane has been removed, and most of the corpuscles are washed away, to show more evidently the transparent soft fibres prolonged from the bone, with the dark earthy deposit advancing into them.

complete tubes or canals in the older and denser part, which run in the same direction. The canals, as well as the grooves, which become converted into canals, contain blood-vessels supported by processes of the investing membrane, which deposit concentric layers of bone within ; and when thus surrounded with concentric laminæ, these tubular cavities are in fact the Haversian canals.

Early condition of temporary cartilages.

Ossification in cartilage.—It has already been stated that in by far the greater number of bones, the primitive soft cellular matter of which they originally consist is very quickly succeeded by cartilage, in which the ossification begins. One of the long bones taken from a very small embryo, just before ossification has commenced in it, is observed to be distinctly cartilaginous. In the tibia of a sheep, for example, at a time when the whole embryo is not more than an inch and a quarter in length, we can plainly see that the substance consists of cartilage cells imbedded in a pellucid matrix. These cells, which can scarcely be said to be collected into groups, are much larger in the middle part of the shaft where ossification afterwards commences, and there also they are mostly placed with their long diameter across the direction of the bone ; towards the ends they are much smaller and closer together, and the cartilage there is less transparent. As it enlarges, the cartilage acquires firmer consistence ; it represents in figure the future bone, though of course much smaller in size, and it is surrounded with a fibrous membrane or perichondrium, the future periosteum. Vessels ramify in this membrane, but none are seen in the cartilage until ossification begins.

Fig. 37'.*

Commencement and progress of ossification.

In a long bone the ossification commences in the middle and proceeds towards the ends, which remain long cartilaginous, as represented in fig. 37'. At length separate points of ossification appear in them, and form epiphyses, which at last are joined to the body of the bone.

* Humerus of a fœtus, natural size. The upper half is divided longitudinally. *a*, Cartilage. *b*, Bone, which terminates towards the cartilage by a slightly convex surface.

The new-formed osseous tissue is red and obviously vascular, and blood-vessels extend a little way beyond it into the adjoining part of the cartilage. In a long bone these precursory vessels are seen at either end of the ossified portion of the shaft, forming a red zone in that part of the cartilage into which the ossification is advancing. The vessels are lodged in excavations or branching canals in the cartilage, (fig. 37′, *a*,) and seem to ramify in these canals, which are much larger than the vessels they contain. Other vascular canals enter the cartilage from its outer surface, and conduct vessels into it directly from the perichondrium; at least, this may be seen when the ossification approaches near to the ends of the bones.

Dr. Baly has observed that in a transverse section of the ossifying cartilage, its cells appear arranged in radiating lines round the sections of the vascular canals; † and I may also remark that in many of these radiating groups the cells successively diminish in size towards the centre, that is, as they approach the canal. It might naturally be asked whether these smaller and more central cells are not more recently deposited, and whether the vascular canals do not minister to the increase of the cartilage; but we are not prepared to give a satisfactory answer to the question. In fact, the precise relation of these canals to the process of ossification is not understood; it is certain, however, that the cavities of the future bone are not formed out of them, as some have supposed.

Fig. 38′.*

Minute examination.

To examine the process more minutely, let an ossifying bone be divided lengthwise, as in

* Thin longitudinal section of ossifying cartilage from the humerus of a fœtal sheep, magnified about 70 diameters. *a*, Cartilage cells uniformly diffused. *b*, Cells nearer the surface of ossification, collected into piles or oblong groups. *c*, Bone shooting up between the groups of cells and forming oblong areolæ.

† Müller's Physiology, plate I., fig. 16.

fig. 37′, and then from the surface of the section (as at *a*, *b*) take off a thin slice of cartilage, including a very little of the ossified part, and examine it with the microscope. Such a view, seen with a low power, is shown in fig. 38′. The cartilage at a distance from the surface of the ossified part has its cells uniformly disseminated in the matrix, (as at *a*, where it appears in the figure as if granular,) but at and near to the limit where the ossification is encroaching upon it, the cells are gathered into rows or oblong groups, between which the transparent matrix appears in form of clear longitudinal lines obliquely intersecting each other (*b*). Tomes and De Morgan state that these rows are formed by segmentation of the cartilage cells transversely to the line of ossific advance. Turning now to the newly-formed bone (*c*), which from its dark opaque aspect contrasts strongly with the cartilage, and tracing it towards their mutual boundary, we see plainly the dark lines of ossification shooting up into the clear spaces of the cartilage between the groups of corpuscles; it is evident, in short, that the earthy deposit proceeds through the matrix, and that the new osseous substance forms in the first instance oblong areolæ or loculi, which inclose the groups of cells. This is further illustrated by a thin transverse section, carried nearly parallel to the ossifying surface, and partly encroaching on it, so as to take off a little of the bone along with the cartilage, as represented in fig. 39′. In this view we see at one part the nearly circular sections of the newly-formed osseous areolæ; at another, sections of the rows of cartilage cells with the clear matrix between and around them, and into this the dark ossification is advancing.

Changes in ossifying cartilage.

Primary condition of the osseous structure.

Fig. 39′.*

* Transverse section of the ossifying cartilage represented in fig. 38′. made a little above *c*, along the surface of ossification, and including part of the new bone, magnified 70 diameters. The circular sections of the groups of cells and of the osseous areolæ are seen; and the dark bone extending into the clear intercellular matrix.

On using a higher power, as in fig. 40′, it will be seen that the cells forming the groups are placed with their long diameter transversely, as if they had been flattened and piled upon one another; but in the immediate vicinity of the bone they become greatly enlarged and more rounded. Most of them have an outline distinct from that of the mass within. As to the matter they contain, in some it is a pellucid substance, strongly refracting the light, and nearly filling their cavity; in others it is faintly granular and light like ground glass, and has a well-defined outline, and in these there is a very distinct nucleus, varying much in size in different cells, but always most regularly circular, and inclosing one or more nucleoli; lastly, a good many cells may be seen, the mass contained in which does not nearly fill the cavity, and is usually coarsely granular or grumous, with an uneven, and in some, a jagged outline. There seems reason to believe that the granular mass within the cartilage cells is included in a delicate envelope closely applied to it, which has been considered as corresponding to the primordial utricle of vegetable cells. Messrs. Tomes and De Morgan have distinguished it by the name of the "granular cell." Changes in cartilage cells more particularly.

Fig. 40′.*

It thus appears that the bony tissue, as it advances into the cartilage, has at first a sort of alveolar structure, forming fusiform *areolæ* or short tubular cavities, with thin parietes. But this condition, which differs from that of perfect bone, is only transitory, and at a short distance below the ossifying surface we see a change taking place in the newly-formed tissue; the structure becomes more open, the cartilage cells (some after previous calcification, others not) for the most part disappear from its interstices, and the cancelli Changes in the primary osseous tissue.

* Fig. 40′, small portion of a section similar to that in fig. 38′, more highly magnified (about 140 diameters). *a*, *b*, Two of the new-formed osseous tubes or areolæ, with a few cartilage cells and granular corpuscles, lying in them. *c*, *c*, Cartilage cells near the ossifying surface, exhibiting the appearances described in the text.

and Haversian canals, with their concentric lamellæ, begin to be formed. This, which is the next step of the process, appears to take place in the following manner. The *primary areolæ* of the bone above described open into one another by absorption of their intermediate walls, both laterally and longitudinally, and it is mainly to their confluence that the formation of the larger, or what might be termed *secondary cavities*, which succeed them lower in the bone, is due. This is shown in fig. 41′ A, which represents a thin transverse section, made almost immediately below the surface of ossification, and in which the primary

Primary areolæ coalesce into secondary cavities.

Fig 41′ A.*

Fig. 41′ B.*

cavities are seen to have coalesced into larger ones. A section somewhat lower (fig. 41′ B), shows that they go on

Thickening of parietes

* A and B represent two transverse sections of growing bone, as in

enlarging by further coalescence, and that their sides are thickened by layers of new bone; this soon begins to be deposited (fig. 41′ A), and goes on increasing (B). In the mean time the cartilage cells have disappeared, and the bony cavities are filled with blastema, in which there are a few fibres and numerous granular corpuscles or cells resembling those seen in the intramembranous ossification; there are also many blood-vessels. In the end some of the enlarged cavities remain to form the cancellated structure; while others getting more and more filled up with concentric lamellæ, become Haversian canals; although the Haversian canals of the compact sides of the bone, it may be remarked, principally arise in another way, as will be afterwards described. In many of these cavities the walls of the coalesced primary areolæ may long be distinguished, like little arches, forming by their union a sort of festooned outline, within which the new bony laminæ are situated. by secondary deposit.

The primary osseous matter forming the original thin walls of the areolæ is decidedly granular and has a dark appearance; the subsequent or *secondary deposit* on the other hand is quite transparent and of an uniform, homogeneous aspect, as if the granules had coalesced; at any rate they are no longer distinguishable. This secondary deposit begins to cover the granular bone a very short distance (about $\frac{1}{60}$th of an inch) below the surface of ossification, and, as already stated, increases in thickness further down. The lacunæ first appear in this deposit; there are none in the primary granular bone. It is most generally supposed that the new deposit is formed of cells which become impregnated with earthy matter,—the cartilage cells in the first instance, and afterwards cells newly formed in the blastema—the *osteal cells* of Tomes and De Morgan—but although certain appearances render it not improbable that there may be a layer of flattened and calcified cells next to the surface of the granular bone, I am nevertheless disposed to think that the subsequent and chief part of the deposit results from the calcification of successive layers of fibres, generated in the blastema, some cells being involved along with them, and probably contributing to form lacunæ,

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fig. 39′, but much more magnified (about 120 diameters). They show the lateral coalescence of the primary bony areolæ and the thickening of the sides of the enlarged cavities by new osseous deposit. The section A is made almost immediately below the surface of ossification; B is somewhat lower, and shows the cavities still more enlarged and their sides more thickened than in A. The new osseous lining is transparent and appears light in the figures; the dark ground within the areolæ is owing to opaque debris, which collected there in grinding the sections. It must be further noticed that the letter A within the larger figure marks a place where a bony partition had been accidentally broken away, so that the large space was naturally divided into two.

as in the ossification of the flat bones of the cranium; in short, it appears to me that the deposit in question is formed after the manner of the intramembranous ossification already described (page cxxviii.) I infer that such is the process from the structure of the layers; for they are made up of fine reticulated fibres, like the lamellæ of perfect bone, shown at page cxx. On a careful inspection, and with a certain adjustment of the light, fine striæ may be seen in many parts indicating the obliquely decussating fibres of the new-formed laminæ. The structure in some measure reminds us of the secondary deposit inside the oblong cells of the wood of coniferous trees, in which the ligneous matter is arranged in fibres, or rather in fine lines, running obliquely round the wall of the cell and crossing one another in alternate layers.

Kölliker has observed that in the ossification of rickety bones the groups of cartilage cells included in the primary osseous areolæ are calcified, a lacuna only being left in the centre of each cell. He believes that the same thing takes place in the natural process of ossification, and that the growing bone forms at first a compact layer of some thickness in the neighbourhood of the cartilage, in which the intercommunicating medullary cavities are afterwards excavated by absorption, without regard to previously existing structure. The observations, moreover, of Tomes and De Morgan satisfactorily show that part at least of the cartilage cells are calcified and converted into lacunæ in normal bone; still I consider that the cavernulation of the new bone is owing chiefly to confluence of the primary areolæ from absorption of their party walls, as shown in figs. 41′, A and B; most of the cartilage cells having disappeared, and probably in great part without previous calcification.

Origin of the lacunæ.

The mode of production of the lacunæ, or so-called corpuscles of bone, is perhaps not yet fully understood. They are generally supposed to be derived from the cells of the soft tissue involved in the ossification by a process which has been variously explained. Schwann supposed that the cell becomes the lacuna, and sends out branches to form the canaliculi which anastomose with similar prolongations from neighbouring cells. Were this statement modified by assuming that the cell retains permanently its original soft character, but becomes exactly inclosed in a bony cavity of corresponding shape, formed by calcification of the surrounding tissue, it would correspond with the view lately promulgated by Virchow and Kölliker on the formation of lacunæ in the ossification of fibro-cellular blastema. As to the production of lacunæ from cartilage cells, Henle compared the process to that of the formation of pore-cells in the hard tissues of plants. He conceived that the cell becomes filled up by calcification, except in the centre where an irregular cavity remains as the lacuna, with branched passages extending from it and forming the canaliculi, which are also left unfilled in consequence of the unequal deposition of the hard matter. It is obvious, however, that this explanation does not account for the great extension of the canaliculi and their intercommunication with those of neighbouring lacunæ; if indeed lacunæ derived from cartilage cells do really thus communicate. Kölliker, adopting a view, which would seem to have been independently arrived at by more than one histologist, as to the homology of cartilage and vegetable cellular tissue, conceives that a cartilage cell consists of, 1. an exterior envelope which he proposes to call the "cartilage capsule," usually distinct in yellow cartilage (see fig. 31′), but in hyaline cartilage for the most part blended with the matrix; 2. an interior vesicle immediately inclosing the cell contents

and nucleus. The matrix and "cartilage capsules" he regards as homologous with the vegetable cellulose, (periplast of Huxley), the capsule corresponding with the cellulose wall of the vegetable cell. The interior vesicle (distinguished by Tomes and De Morgan as the "granular cell") he considers as representing the "primordial utricle" of the vegetable cell (endoplast of Huxley). In the process of ossification the matrix is calcified, together with its appertaining cartilage capsules. The capsule becomes thickened by osseous deposit and encroaches on the space within, but unequally, as in the formation of vegetable pore-cells, leaving, as in that case, a central cavity with prolongations radiating from it to the circumference of the cell, whilst the primordial utricle, untouched by the calcifying process, remains within the cavity and corresponds with it in figure. To account for the anastomosis of the canaliculi with those of neighbouring lacunæ, Kölliker has no hesitation in assuming that they are prolonged by absorption through the cartilage capsule and into the matrix beyond it, and while he professes his inability to trace the process by actual observation, he thinks that the included branches of the primordial utricle may be in some way instrumental in effecting it. In the intramembranous ossification the ramified cell has no outer capsule as in cartilage, and is accordingly regarded as representing the primordial utricle of vegetables and the interior (or granular) cell of cartilage, whilst the surrounding blastema corresponds with the vegetable cellulose. Persistent lacunæ derived from cartilage cells exist but scantily in the skeleton. Well-marked examples, however, occur in articular cartilage and in that of the pubic symphysis, when, as commonly happens, the part of these tissues adjoining the bone is encroached on by ossification, as noticed at page cxxi. The ossifying process in this case is a mere calcification of the cartilage, and stellate lacunæ, not intercommunicating, remain in the partially ossified cells. When the tissue is decalcified by an acid the original cells and cartilaginous matrix become apparent.

Messrs. Tomes and De Morgan distinguish two kinds of cells as concerned in the formation of bone. 1. *Lacunal cells;* these consist of an interior "granular cell" and an outward transparent envelope. Cartilage cells belong to this head; their exterior envelope (cartilage capsule, Köll.) acquires increased thickness and definition as they approach the region of ossification, and then the interior or granular cell (primordial utricle) commonly assumes an irregularly stellate form like that of the future lacuna which remains in the centre after the rest of the cell is calcified. 2. *Osteal cells,* which have a round or oval figure and granular aspect. These are described as abounding in the blastema of the non-cartilaginous ossification and as forming the growing bone by their aggregation and calcification. They are supposed to correspond to the granular cells contained within the lacunal cells of cartilage, and according to the authors referred to, a certain number of them acquire an outer transparent envelope and become lacunal cells to be employed in the production of lacunæ in bone formed independently of cartilage.

As ossification thus advances towards the ends of the bone, the portion as yet cartilaginous continues to grow at the same time and increases in every dimension. The part already osseous increases also in circumference; the medullary cavity, of which for some time there is no

Continued growth of cartilage and increase of osseous part.

Formation

of medullary canal. appearance, begins to be excavated in its interior by absorption, and the sides of the shaft acquire compactness and solidity. The increase in girth is brought about by deposition of bone at the surface underneath the periosteum.

Nature of subperiosteal ossification. It has been sometimes supposed that a formation of cartilage precedes the bone also in this situation; but such is not the case, for the vascular soft tissue in immediate contact with the surface of the growing bone is not cartilage, but a blastema containing fibres and granular corpuscles; in fact, the increase takes place by intramembranous ossification, and accordingly the Haversian canals of the shaft are formed in the same way as those of the tabular bones of the skull,—that is, the osseous matter is not only laid on in strata parallel to the surface, but is deposited around processes of the vascular membranous tissue which extend from the surface obliquely into the substance of the shaft; and the canals in which these vascular processes lie, becoming narrowed by the deposition of concentric osseous laminæ, eventually remain as the Haversian canals.

Fig. 42′.*

That the ossification at the periosteal surface of the bone does not take place in cartilage, may be made apparent in the following manner. Strip off the periosteum from the bone at the end of the shaft, and from the adjoining cartilage also, taking care not to pull the latter away from the bone. A thin membranous layer will still remain, passing from the bone to the surface of the cartilage; now, take a thin slice from the surface, including this membrane with a very thin portion of the bone and of the cartilage, and examine it with the microscope, scraping off the cartilage from the inside if it be too thick. It will then be seen that the superficial part or shell of the bone, if it may be so called, is prolonged a little way over the surface of the cartilage by means of pellucid, coarsely reticulated fibres of soft tissue, (fig. 42′, *b*, *c*,) into which the earthy

* Subperiosteal layer from the extremity of the bony shaft of the ossifying tibia, as described in the text. The cartilage and more open bony tissue have been scraped off from the inside of the crust, except at *a*, where a dark shade indicates a few vertical osseous areolæ out of

deposit is advancing. These fibres are intermixed with granular corpuscles or cells, but form no part of the cartilage, and they are no doubt of the same nature as those seen in the intramembranous ossification of the skull. Their reticulations are in most cases directed transversely, and sometimes they are little, if at all, in advance of the limit between the bone and cartilage. I have observed the structure here described in several bones of the (well advanced) fœtal sheep, also in the human scapula, humerus, femur, tibia and fibula, metacarpus and metatarsus, and it has since been found in all the long bones.

Ossification having thus proceeded for some time in the shaft, at length begins in the extremities of the bone from one or more independent centres, and extends through the cartilage, leaving, however, a thick superficial layer of it unossified, which permanently covers the articular end of the bone. The epiphyses thus formed continue long separated from the shaft or diaphysis by an intervening portion of cartilage, which is at last ossified and the bone is then consolidated. The time of final junction of the epiphyses is different in different bones; in many it does not arrive until the body has reached its full stature. In the mean time the bone increases in length by the ossification continuing to extend into the intervening cartilage, which goes on growing at the same time; and it appears that in the part of the shaft already ossified, little or no elongation takes place by interstitial growth. This is shown by an experiment first made by Dr. Hales and afterwards by Duhamel and by John Hunter, in which two or more holes being bored in the growing bone of a young animal at a certain measured distance from each other, they are found after a time not to be farther asunder, although the bone has in the meanwhile considerably increased in length.* In like manner the shaft also increases in circumference by deposition of new bone on its external surface, while at the same time its medullary canal is enlarged by

Formation of epiphyses.

Increase of bone in length.

In circumference.

focus and indistinctly seen. The part *a*, *b*, of the crust is ossified; between *b* and *c* are the clear reticulated fibres into which the earthy deposit is advancing. Magnified 150 diameters.

* Hales. Veget. Statics, 4th edit. p. 340. Duhamel Mem. de l'Ac. des Sc. 1743 and seq. Hunter (reported by Home) in Trans. of Soc. for Imp. of Med. and Chir. Knowledge, vol. ii.; also Catalogue of Hunterian Museum, vol. i. p. 249. Duhamel was led from some of his experiments to infer that an interstitial elongation took place near the ends; but there is some doubt left as to the precise circumstances of the experiments in these cases. Both Hales and Duhamel, in experimenting on the growing tibia of a chicken, observed that the addition of new bone was much greater at the upper end.

absorption from within. A ring of silver or platinum put round the wing-bone of a growing pigeon, becomes covered with new bone from without, and the original bone included within it gets thinner, or, according to Duhamel, who first made the experiment, is entirely removed, so that the ring comes to lie within the enlarged medullary canal.

Conclusions from experiments with madder.

Madder given to an animal along with its food, tinges the earth of bone, which, acting as a sort of mordant, unites with and fixes the colouring matter. Now, that part of the bone which is most recently formed, and especially that part which is actually deposited during the administration of the madder, is tinged both more speedily and more deeply than the older part, and, as in this way the new osseous growth can be readily distinguished from the old, advantage was taken of the fact by Duhamel and afterwards by Hunter in their inquiries as to the manner in which bones increase in size. By their experiments it was shown that when madder is given to a young pig for some weeks, the external part of its bones is deeply reddened, proving that the new osseous matter is laid on at the surface of that previously formed; again, it was found that when the madder was discontinued for some time before the animal was killed, an exterior white stratum (the last formed) appeared above the red one, whilst the internal white part, which was situated within the red, and had been formed before any madder was given, had become much thinner; showing that absorption takes place from within. In this last modification of the experiment also, as noted by Mr. Hunter, a transverse red mark is observed near the ends of the bone, beyond which they are white; the red part indicating the growth in length during the use of the madder, and the white beyond, that which has taken place subsequently,—thus showing that the increase in length is caused by the addition of new matter to the extremities.* But other changes take place in the bone. The spaces in the cancellated structure become enlarged, as well as the medullary canal, by absorption; whilst in other parts the tissue becomes more compact by farther deposit on the inner surface of the vascular cavities. The sides of the shaft in particular acquire greater solidity by the narrowing of the Haversian canals, within which the vascular membrane continues to deposit fresh layers of bone; and madder administered while this process is going on, colours the interior and recently-formed laminæ, so that in a cross section the Haversian apertures appear surrounded with a red ring. Lastly, Tomes and De Morgan have shown that in bones which have acquired their full size, a production of new systems of Haversian lamellæ continues throughout life, as described at page cxvi.

Remark as to relation of cartilage and bone.

From the foregoing account it is evident that a great portion of a long bone is formed independently of cartilage.† Those physiologists, there-

* M. Flourens has repeated and varied these experiments, and represented the results in beautiful delineations. Recherches sur le Developpement des Os et des Dents. Paris, 1842.

† This statement was published by me in 1846, and from that time I have usually illustrated the point in my Lectures by a scheme similar to that given by Kölliker, in his Mikroskopische Anatomie, vol. ii. fig. 115.

fore, appear to have reason on their side, who consider the pre-existence of that tissue as not being a necessary condition of the ossific process, and who regard the precursory cartilage of the fœtal skeleton chiefly in the light of a temporary substitute for bone, and also as affording as it were a mould of definite figure and of soft but yet sufficiently consistent material in which the osseous tissue may be at first deposited and assume a suitable form.

Time of ossification.

The time of commencement of ossification in the different bones, as well as the number and mode of conjunction of their bony nuclei, are subjects that belong to special anatomy. It may, however, be here remarked in general, that the commencement of ossification does not in all cases follow the order in which the bones appear in their soft or cartilaginous state. The vertebræ, for instance, appear as cartilages before there is any trace of the clavicle, yet ossification begins in the latter sooner than in any other bone of the skeleton. The time when it commences in the clavicle, and consequently the date of the first ossification in the skeleton, is referred by some to the seventh week of intra-uterine life; others assign a considerably earlier period; but owing to the uncertainty that prevails as to the age of early embryos, the dates of commencing ossification in the earliest bones cannot be given with precision.

Number of nuclei or centres of ossification.

In regard to the number and arrangement of the nuclei, the following general facts may be stated :—1. In the long bones there is one centre of ossification in the middle, and the ends are for the most part ossified from separate nuclei; whilst a layer of cartilage remains interposed until the bone has nearly attained its full length. By this means the bone is indurated in the parts where strength is most required, whilst its longitudinal growth is facilitated. 2. The larger foramina and cavities of the skeleton are for the most part formed by the junction of two, but more generally of three or more nuclei round the aperture or included space. The vertebral rings, the acetabulum, the occipital foramen, and the cranium itself, are illustrations of this. It is easy to conceive that in this way the ready and equable enlargement of such cavities and apertures is provided for. 3. Bones of a complex figure, like the vertebræ, have usually many nuclei; but the converse is not always true. 4. We can frequently connect the number of nuclei with the principle of uniformity of type on which the skeleton of vertebrated animals is constructed. Thus the typical form of the sternum seems to be that of a series of distinct bones, one placed between each pair of ribs in front, as the vertebræ are behind, and this is its permanent condition in many quadrupeds. In man it conforms to the archetype in its mode of formation, in so far as it is ossified from several centres and for some time consists of several pieces; but, to suit the fabric of the human thorax, these at last coalesce one with another, and are reduced in number to three.

Reunion and regeneration of bone.

In the reunion of fractured bones, osseous matter is formed between and around the broken ends, connecting them firmly together; and when a portion of bone dies, as happens in necrosis, a growth of new bone very generally takes place to a greater or less extent, and the dead part is thrown off. The several steps of the process of restoration in these instances are so fully described in works on Surgical Pathology, that it is unnecessary to add to the length of this chapter by introducing an account of them here.

MUSCULAR TISSUE.

General nature.

The muscular tissue is that by means of which the active movements of the body are produced. It consists of fine fibres, which are for the most part collected into distinct organs, called muscles, and in this form it is familiarly known as the flesh of animals; these fibres are also disposed round the sides of cavities and between the coats of hollow viscera, forming strata of greater or less thickness. The muscular fibres are endowed with *contractility*, a remarkable and characteristic property, by virtue of which they shrink or contract more or less rapidly under the influence of certain causes which are capable of exciting or calling into play the property in question, and which are therefore named *stimuli*. A large class of muscles, comprehending those of locomotion, respiration, expression, and some others, are excited by the stimulus of the will or volition, acting on them through the nerves; these are therefore named "voluntary muscles," although some of them habitually, and all occasionally, act also in obedience to other stimuli. There are other muscles or muscular fibres which are entirely withdrawn from the control of the will, such as those of the heart and intestinal canal, and these are accordingly named "involuntary." These two classes of muscles differ not only in the mode in which they are excited to act, but also to a certain extent in their anatomical characters; and on this account we shall consider the structure of each class separately.

Voluntary muscles.

Of the structure of voluntary muscles. — The voluntary muscular fibres are for the most part gathered into distinct masses or muscles of various sizes and shapes, but most generally of an oblong form, and furnished with tendons at either extremity, by which they are fixed to the bones.

Attachments, *origin*, and *insertion*.

The two attached extremities of a muscle are named, in anatomical descriptions, its origin and insertion, — the former term being usually applied to the attachment which is considered to be most fixed, although the rule cannot be always applied strictly. The fleshy part is named the belly, which in some cases is interrupted in the middle or divided into two by a tendon, and then the muscle is said to be biventral or digastric; on the other hand it may be cleft at one end into two or three portions, in which case it is named bicipital or tricipital.

The muscular fibres are collected into packets or bundles, of greater or less thickness, named fasciculi or lacerti (fig. 43′), and the fibres themselves consist of much finer threads

Division into *fasciculi*, *fibres*, and *fibrillæ*.

Fig. 43′.*

Fig. 44′.†

visible by the aid of the microscope, which are termed muscular filaments, fibrillæ or fibrils (fig. 44′, *c*). The fibrils run parallel with each other in the fibres, and the fibres are parallel in the fasciculi, and both extend continuously from one terminal tendon to the other, unless in those instances, like the rectus muscle of the abdomen and the digastric of the inferior maxilla, in which the fleshy part is interrupted by interposed tendinous tissue. The fasciculi also very generally run parallel, and although in many instances they converge towards their tendinous attachment with various degrees of inclination, yet in the voluntary muscles they do not interlace with one another.

Sheath.—An outward investment or sheath of areolar tissue surrounds the entire muscle, and sends partitions inwards between the fasciculi; furnishing to each of them a special sheath. The areolar tissue extends also between the fibres, but does not afford to each a continuous invest-

Sheath.

* A, a small portion of muscle, natural size; B, the same magnified 5 diameters, consisting of larger and smaller fasciculi, seen in a transverse section.

† A few muscular fibres, being part of a small fasciculus, highly magnified, showing the transverse striæ. *a*, End view of *b b*, fibres. *c*, A fibre split into its fibrils.

ment, and therefore cannot be said to form sheaths for them. Every fibre, it is true, has a tubular sheath; but this, as will be afterwards explained, is not derived from the areolar tissue. The areolar tissue of the sheath is composed of elastic (yellow) as well as white fibres; but the elastic element is found principally in its investing (as distinguished from its penetrating) portion. The chief uses of the areolar tissue are no doubt to connect the fibres and fasciculi together, and to conduct and support the blood-vessels and nerves in their ramifications between these parts. The relation of these different subdivisions of a muscle to each other, as well as the shape of the fasciculi and fibres, is well shown by a transverse section. Figs. 43′ and 44′.

Shape, size, and arrangement of the fasciculi.

Fasciculi.—The fasciculi are of a prismatic figure, and their sections have therefore an angular outline. The number of fibres of which they consist varies, so that they differ in thickness, and a larger fasciculus may be divisible into two or three orders of successively smaller bundles, but of no regularly diminishing magnitude. Some muscles have large, others only small fasciculi; and the coarse or fine texture of a muscle, as recognised by the dissector, depends on this circumstance. The length of the fasciculi (and consequently that of the fibres and filaments) is not always proportioned to the length of the muscle, but depends on the arrangement of the tendons to which their extremities are attached. When the tendons are limited to the ends of a long muscle, as in the sartorius, the fasciculi, having to pass from one extremity to the other, are of great length; but a long muscle may be made up of a series of short fasciculi attached obliquely to one or both sides of a tendon, which advances some way upon the surface or into the midst of the fleshy part, as in the instance of the rectus muscle of the thigh, and the tibialis posticus. Muscles of the kind last referred to are named "penniform," from their resemblance to the plume of a feather, and other modifications of the arrangement, which can be readily conceived, are named "semipenniform" and "compound penniform." Many short fasciculi connected thus to a long tendon, produce by their combined effect a more forcible contraction than a few fasciculi running nearly the whole length of the muscle; but by the latter arrangement the extent of motion is greater, for the points of attachment are moved through a larger space.

Fibres, their size.

Of the fibres.—The fibres, although they differ somewhat

in size individually, have the same average diameter in all the voluntary muscles, namely, about $\frac{1}{400}$th of an inch; and this holds good whether the muscles be coarse or fine in their obvious texture. According to Mr. Bowman * their average size is somewhat greater in the male than in the female, being in the former $\frac{1}{332}$, and in the latter $\frac{1}{454}$, or more than a fourth smaller. When viewed by transmitted light with a sufficiently high power of the microscope, the fibres, which are then clear and pellucid in their aspect, appear marked with very fine dark parallel lines passing across them directly or somewhat obliquely, at exceedingly short but regular intervals. (Fig. 44′.) The lines, as just mentioned, are dark; and the intervals between them light; their distance apart is about $\frac{1}{9400}$th of an inch, and they are even closer together in parts of a muscle which happen to be contracted. This cross-striped appearance, which is most beautiful and characteristic, is found in all the voluntary muscles; but it is not altogether confined to them, for it is seen in the fibres of the heart, which is a strictly involuntary organ: striped fibres are also found in the pharynx and upper part of the gullet, in the muscles of the internal ear, and those of the urethra, parts which are not under the direct control of the will.

Generally speaking, the fibres neither divide nor anastomose; but on the contrary maintain an undivided course from one of their extremities to the other. This rule is, however, not without exception. Branched and anastomosing fibres are common in the heart; in the tongue of the frog also, the muscular fibres as they approach the surface divide into numerous but not anastomosing branches, by which they are attached to the under surface of the mucous membrane; and the fibres of the facial muscles of mammals have been shown by Busk and Huxley to divide in a similar manner where they fix themselves to the skin.

Structure of the fibres. As to the structure of the fibres, it has been ascertained that each is made up of a large number of extremely fine filaments or fibrils, inclosed in a tubular sheath. The proper sheath of the fibre, which was discovered nearly about the same time and independently by Schwann and by Bowman, has been named by the latter the "sarcolemma." **Sheath, or sarcolemma.**

* I shall have frequent occasion in this chapter to refer to Mr. Bowman's important researches on muscle. Phil. Trans. 1840 and 1841, and Cyclopædia of Anatomy, art. "Muscle," and "Muscular Motion."

It consists of transparent and apparently homogeneous membrane, and, being comparatively tough and elastic, will sometimes remain entire when the included fibrils are ruptured by stretching the fibre, as represented in fig. 45′. In this way its existence may be demonstrated, and it is especially well seen in fish and other animals which have large fibres, for in such instances it is thicker and stronger. It may also be shown by immersing a fibre in water before irritability is extinguished; the fluid is in this case first imbibed by the fibre, and then, exciting contraction, is squeezed out of its substance, when it usually collects between the fibre and its sheath, and raises the membrane into vesicles or bullæ. It may be doubted whether the existence of a distinct sarcolemma is universal in striated muscles. Busk and Huxley state that they have been unable to detect it in muscular fibres from the heart and tongue.

Fig. 45′.*

Fibrils.

Fibrils.—Lines and fissures are sometimes seen running lengthwise in the substance of the fibres, and indicating their fibrillar structure, as in some of those represented in fig. 44′; and when these longitudinal lines are well marked, the transverse striæ are comparatively indistinct. In a thin transverse section the ends of the fibrils may be seen, when highly magnified, as small dots or points, which occupy the whole sectional area of the fibre, showing plainly that the latter is not hollow, as has sometimes been maintained, but possesses the same fibrillar structure throughout its whole thickness. The fibrils may be partially separated and spread out by breaking across a fibre, and gently bruising the broken end, as at *d*, fig. 44′, or by splitting up its substance with fine needles. But it is no easy matter to insulate a single fibril; and to succeed in this, a perfectly fresh and favourable specimen, as well as nice manipulation, is required. When a fibril thus completely insulated is highly magnified, it is seen to consist of a single row of minute particles, connected together like a string of beads.

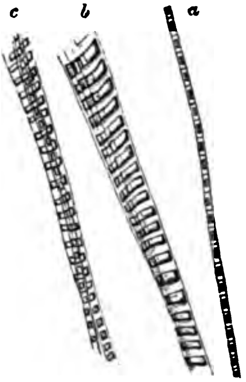
Elementary particles.

These particles (named "sarcous elements" by Bowman),

* Fragments of a muscular fibre of the skate, held together by the twisted sarcolemma. After Bowman, Cycl. of Anat. fig. 294.

when viewed with a magnifying power of 400 or 600, appear like little dark quadrangular and generally rectangular bodies, with bright intervals between them, as if they were connected together by some pellucid substance, *a*, fig. 46′; but on closer examination, provided the defining power of the instrument is good, a very faint or dark line or shadow will be discovered passing across the fibril in the middle of each of the bright spaces, and sometimes also a bright border may be perceived on either side of the fibril, so that each of the rectangular dark bodies appears then to be surrounded with a bright area having a similar quadrangular outline, as represented in the figure, and it may therefore be inferred that the pellucid substance incloses it on all sides. In short, it would seem that the elementary particles of which the fibril is made up, are little masses of pellucid substance, presenting a rectangular outline, and appearing dark in the centre. Their appearance, indeed, has suggested the notion of minute vesicular bodies or cells, cohering in a linear series, the faint transverse marks between being the lines of junction. But although this idea very naturally presents itself, we must not assume that the reality of it is established. With a still higher magnifying power, the dark central part appears constricted in the middle, or looks as if it consisted of two portions joined together. When the focus is altered, the internal dark part becomes light; it is therefore evidently transparent, and its dark aspect is probably owing to its refracting the light differently from the surrounding

Fig. 46′.*



* Muscular fibrillæ of the pig magnified 720 diameters. *a*, An apparently single fibril, showing the quadrangular outline of the component particles, their dark central part and bright margin, and their lines of junction, crossing the light intervals. *b*, A longitudinal segment of a fibre consisting of a number of fibrils still connected together. The dark cross stripes and light intervals on *b* are obviously occasioned by the dark specks and intervening light spaces respectively corresponding in the different fibrils. *c*, Other smaller collections of fibrillæ. From a preparation by Mr. Lealand.

substance.* Minute pellucid objects indeed exhibit, when highly magnified, a dark centre surrounded by a bright halo, if viewed a little within the true focal distance; but the bright circumference of the muscular particles seems to be something more than can be accounted for in this way.

There is some difference of statement as to the microscopic appearances presented by muscular fibrils under high magnifying powers, and still more difference of opinion respecting the right interpretation of the phenomena. According to Dobie, Busk and Huxley, and others the faint dark lines crossing the fibril in the middle of the light intervals are not visible in the striated muscles of all animals. Busk and Huxley state that they are wanting in many of the muscular bundles of mammals. These observers suggest that the lines in question are produced by the interposition of rows of minute, pale, sarcous elements. Again, while the appearance of clear spaces interposed between the dark particles along the line of the fibril is not doubtful, the apparent enclosure on all sides of each of the dark particles by a border or frame of bright substance, with the resulting vesicular aspect, is considered as illusory by many observers whose opinion is entitled to great respect.

Cause of the cross striæ.

When the fibrillæ lie undisturbed in the fibre, the elementary particles of collateral fibrils are situated in the same transverse plane, and it is to this lateral coaptation of the particles that the transverse striping of the fibre is due. (See *b*, fig. 46′.) Accordingly, the cross lines are not confined to the surface of the fibre, but may be seen throughout its entire thickness on successively deepening the focus of the microscope. The fibres moreover often show a tendency to cleave across in the direction of these lines, and even to break up into transverse plates or disks, which are formed by the lateral cohesion of the particles of adjacent fibrils. To make up such a disk, therefore, every fibril contributes a particle, which separates from those of its own fibril, but coheres with its neighbours on either side, and this with perfect regularity. Indeed, Mr. Bowman

Transverse cleavage of the fibres.

* Various observers, from the time of Hooke in the seventeenth century to the present day, have recognised a beaded structure in the muscular filaments. Muys, who however considered the beaded appearance as only occasional, and seems to have been a good deal perplexed by it, represents the particles as rectangular. Invest. Fabricæ quæ in part. musc. comp. extat. Lugd. Bat. 1741. Tab. I. fig. 17. Their quadrangular outline was fully and clearly shown by Mr. Bowman. The faint lines passing across the light intervals between the dark particles, as well as the surrounding bright areas, were, as far as I know, first pointed out by Mr. Lealand, the well-known optician. The figure (46′) was drawn by my friend, Mr. J. Marshall, from a specimen prepared by Mr. L.

conceives that the subdivision of a fibre into fibrillæ is merely a phenomenon of the same kind, only of more common occurrence, the cleavage in the latter case taking place longitudinally in place of transversely: accordingly, he considers that the fibrillæ have no existence as such in the fibre, any more than the disks; but that both the one and the other owe their origin to the regular arrangement of the particles of the fibre longitudinally and transversely, whereby, on the application of violence, it cleaves in the one or in the other direction into regular segments.

Mr. Bowman finds that the size of the elementary particles is remarkably uniform in mammalia, birds, reptiles, fishes, and insects. Size of the elementary particles.

A number of pale, finely granular, *oval* corpuscles, resembling cells or cell nuclei, are scattered among the fibrillæ in the substance of the fibres, or upon the inner surface of the sarcolemma. These have been supposed to be connected with the growth and nutrition of the muscle. They are obvious in the fœtus some time before birth, but afterwards the addition of acetic acid is required in order to render them visible. They flow out with the contents of the fibre when the latter have been disintegrated by the action of potash. Other corpuscles, usually reckoned along with these just described, are distinguished by Mr. Ellis * under the name of *fusiform* corpuscles. These have a very dark outline with a scarcely granular interior; their shape is usually fusiform with pointed ends, but sometimes they are truncated and often twisted or subdivided. Their breadth is from $\frac{1}{20000}$ to $\frac{1}{14000}$ and their length $\frac{1}{1400}$ to $\frac{1}{700}$ of an inch. They are similar to the fusiform corpuscles brought into view by acetic acid in nerves and tendons, and are considered by Mr. Ellis to be of the same nature as those belonging to the so-called nuclear or elastic fibres of connective tissue. Accordingly they appear to be seated not in the muscular fibres but in the tissue investing the fibres. Corpuscles in the fibres.

Connexion with tendons.—According to Professor Kölliker the mode of connexion differs when the muscular fibres are continuous in a direct line with those of the tendon from that which is observed when the former join the latter at a more or less acute angle. In the first case, the two are directly continuous, the muscular fibre being distinguishable Connection of fibres with tendons.

* Paper read to the Royal Society, June 19, 1856.

from that of the fibrous tissue by its striation alone. In the second case, the muscular fibres terminate in conical processes, which are received in corresponding depressions of the tendinous fibre; the connective tissue of the one being continuous with that of the other. Mr. Ellis * describes the connexion of striated muscle with tendon as taking place in all cases in the following manner. When a muscular fibre is about to end in a tendon, its component fibrils are collected into bundles of different lengths and sizes like the roots of a tree. Around each bundle tendinous tissue is collected, forming a sheath which appears gradually to cease as it is continued backwards on the undivided fibre, but how it is attached is not apparent. The muscular fibrils of a bundle in approaching the tendon gradually cease, each having probably its own tendinous thread to fix it. The central bundles of fibrils reach further than the circumferential, and thus when the latter are broken off by attempts made to detach a fibre from its neighbours, the fibre appears to have a pointed ending. Mr. Ellis does not confirm Professor Kölliker's account of the oblique mode of attachment. He states that in such instances as the gastrocnemius and soleus, every fibre is provided with its separate tendon and is continuous with it as above described, and that the increasing thickness of the main tendon from above downwards is due to successive additions, in form of strata, of the contributing tendons from the underlying layers of muscular fibres. In attaching themselves to the skin and mucous membranes, the muscular fibres, according to the careful description of Dr. Salter,† divide into pointed processes or fine filaments which are continuous with those of the connective tissue.

Blood-vessels of muscle, their arrangement.

Blood-vessels.—The blood-vessels of the muscular tissue are extremely abundant, so that, when they are successfully filled with coloured injection, the fleshy part of the muscle contrasts strongly with its tendons. The arteries, accompanied by their associate veins, enter the muscle at various points, and divide into branches; these pass among the fasciculi, crossing over them, and dividing more and more as they get between the finer divisions of the muscle; at length, penetrating the smallest fasciculi, they end in capillary vessels which run between the fibres. The vessels are supported in their progress by the subdivisions of

* Loc. cit. † Art. Tongue, in Cycl. of Anat.

the sheath of the muscle, to which also they supply capillaries. The capillaries destined for the proper tissue of the muscle are extremely small (fig. 47′), they form among the fibres a fine network, with narrow oblong meshes,

Fig. 47′.*

which are stretched out in the direction of the fibres: in other words, they consist of longitudinal and transverse vessels, the former running parallel with the muscular fibres, and lying in the angular intervals between them,—the latter, which are much shorter, crossing between the longitudinal ones, and passing over or under the intervening fibres.

Relation to fibres.

None of the capillary vessels enter the sarcolemma or proper sheath of the fibre, and the nutritious fluid which they convey must therefore reach the finer elements of the muscle by imbibition. Moreover, as the capillaries do not penetrate the fibres, but lie between them, their number in a given space or their degree of closeness will in some measure be regulated by the number and consequently by the size of the fibres; and accordingly in the muscles of different animals it is found that when the fibres are small, the vessels are numerous and form a close network, and *vice versâ*: in other words, the smaller the fibres, the greater is the quantity of blood supplied to the same bulk of muscle, or to the same amount of elementary muscular particles, for, amidst the variations which the fibre presents in different animals, the size of its minuter elements remains wonderfully constant. In conformity with this, we see that in birds and mammalia, in which the process of nutrition is active, and where the rapid change requires a copious supply of material, the muscular fibres are much smaller and the vessels more numerous than in cold-blooded animals, in which the opposite conditions prevail.

Lymphatics.—Of lymphatic vessels in the muscular tissue nothing certain is known. From an examination of the lymphatics which appear to proceed from different muscles, Kölliker infers that small muscles are destitute of such

* Capillary vessels of muscle from an injection by Lieberkühn, seen with a low magnifying power. The specimen was preserved in spirits; when the muscle is dried, the vessels appear much closer.

vessels, and that the few which apparently issue from some of the larger muscles, belong to the sheath and its larger subdivisions, and not to the proper muscular tissue.

Nerves, their distribution in muscle.

Nerves.—The nerves of a voluntary muscle are of considerable size. Their branches pass between the fasciculi, and repeatedly unite with each other in form of a plexus, which is for the most part confined to a small part of the length of the muscle or muscular division in which it lies. From one or more of such *primary* plexuses, nervous twigs proceed and end by finer or *terminal* plexuses formed by slender bundles consisting of two or three primitive tubules each, some of them separating into single tubules. (Fig. 48′.)

Fig. 48′.*

By means of the microscope these fine nervous bundles and single tubules may be observed to pass between the muscular fibres, and, after a longer or shorter course, to return to the plexus. They cross the direction of the muscular fibres directly or obliquely, forming wide arches; and on their return they either rejoin the larger nervous bundles from which they set out, or enter other divisions of the plexus. The nervous filaments are therefore said to form loops or slings among the muscular fibres. In the muscles of fish and amphibia the simple nerve fibres into which the bundles ultimately separate, are themselves divided into two

* Termination of the nerves among the fibres of a voluntary muscle, as seen with the microscope. After Burdach.

or more branches which, after becoming exceedingly attenuated, are lost to view among the muscular fibres. . Free terminations of nerve fibres with or without previous division have also been traced in the muscles of man and mammalia; so that on the whole it appears probable that although the loops unquestionably exist, they are not to be regarded as the terminations of the fibres which form them. The nerve fibres which are for the most part large in the entering branches become much finer in the terminal plexuses, not in consequence of division but by gradual attenuation. It has been thought that the finely divided nerve fibres in the muscles of amphibia at length penetrate the sarcolemma and mingle with the muscular fibrils, but this is denied by others and still remains a question. Seeing that a muscular fibre only here and there encounters a nerve fibre, it is obvious that if the latter does not penetrate the sarcolemma, a great part of the muscular substance can have but an indirect connexion with the nerve.

Nerves of small size accompany the branches of blood-vessels within muscles, but do not reach the capillaries; though destined for the vessels these nerves sometimes communicate with the proper muscular plexuses.

Structure of involuntary muscles.

Involuntary muscles.—The involuntary muscular tissue differs from the voluntary kind, not only in its want of subjection to the will, but also in its external characters. The most remarkable difference is observed in the aspect of the fibres which, except in the heart and a few instances of less note, are unmarked by the cross lines so characteristic of the striped fibre.

Plain fibres.

These plain or unstriped fibres (fig. 49′) are generally of a pale colour; their figure is for the most part roundish or prismatic, but is readily flattened in examination. Some are not above $\frac{1}{7000}$th of an inch in diameter; but the larger measure from $\frac{1}{4300}$th to $\frac{1}{3300}$th (Ellis). Under the microscope they have a peculiar soft aspect, without a strongly-shaded border; and they are marked at short intervals with oblong corpuscles, which give them a very characteristic appearance, especially after the application of acetic acid, which renders the corpuscles much more conspicuous. The substance of the fibres is translucent, but clouded or even finely granular; and in the latter case the granules are sometimes arranged in longitudinal lines. Mr. Bowman considers this last-mentioned appearance as indicative of an approximation towards the structure of the striped fibre, for he has observed the granules to be about

in general, inasmuch as they present transverse striæ. The striæ, however, are less strongly marked, and less regular, and the fibres are smaller in diameter than in the voluntary muscles. Many of the fibres are attached to the tendinous structure connected with the orifices and valves, and as has been already stated, they are seen to divide and anastomose. The tissue of the heart differs also from most other involuntary muscular structures by its deep colour, but it agrees with them in the interlacement of its fasciculi.

Chemical composition of muscle.

Chemical composition of muscle.—The chief as well as the characteristic constituent of the muscular tissue is a variety of fibrin, which, as it differs in some of its properties from blood-fibrin, it has been proposed to name "syntonin." It is insoluble in solution of nitrate or carbonate of potash, but is readily soluble in dilute hydrochloric acid. There can be little doubt that this animal principle is the essential basis of the muscular fibre; but it must be remembered that a piece of muscle subjected to analysis comprehends along with the proper muscular fibres a certain amount of areolar and often of adipose tissue, blood-vessels and nerves; moreover, that the blood cannot be entirely extracted from its small vessels, and that more or less serum (an albuminous fluid) remains in its moist tissue. Accordingly, other ingredients beside fibrin present themselves in the analysis, and are ascribed to the presence of the accessory substances just mentioned. In 100 parts of fresh voluntary muscle of the ox, Berzelius found

Fibrin	15·80
Gelatin	1·90
Albumen, with colouring matter	2·20
Alcoholic extractive, with salts	1·80
Watery extractive, with salts	1·05
Phosphate of lime, with albumen	0·08
Water and loss	77·17
	100·

Braconnot obtained similar results from an analysis of the tissue of the heart, and through the researches of different experimenters, essentially the same chemical constitution has been discovered in the fibres of the iris, in the uterus, in the muscular coat of the intestine, and in that of the gall-bladder and gall-ducts of the ox and ureter of the horse, also in the hypertrophied muscular coat of the human ureter.

Von Bibra estimates the quantity of watery and solid constituents somewhat differently, viz., water, 74·45, solids, 25·55,—4·25 of the latter being fat, derived chiefly from the blood and from the fat-cells in

the muscles. The researches of Liebig and Scherer have added to the list of organic constituents, by dividing the extractive matters into several important proximate principles. Thus, Liebig has discovered kreatine, kreatinine, inosinic, and lactic acid : Scherer has made known the existence of acetic, butyric, and formic acid, together with a peculiar form of sugar, termed inosite. The most important of these elements is kreatine, which appears to be derived from the necessary waste of the muscular tissue ; and is, consequently, found in greatest abundance in the muscles of animals hunted to death, and in that constantly-acting muscle, the heart. Dr. Gregory found in the heart of an ox, 1·37 to 1·42 parts of kreatine in 1000.

Physical properties. — A dead muscle possesses little strength, and may be lacerated by a force of no great amount. Although it has but little elasticity, the muscular tissue is nevertheless capable of being slowly stretched out in the living body, and will afterwards return to its original state, as happens from the growth of tumours, the accumulation and subsequent removal of dropsical waters, the enlargement and subsidence of the uterus, and such like causes. The red colour of muscle is well known, but it differs greatly in degree in different cases. It is usually paler in the involuntary muscles ; but here the heart again is a striking exception. In fish the chief muscles of the body are nearly colourless, and in the breast of wild fowl we see a difference in the depth of colour in different strata of the same muscles. The redness is no doubt partly due to blood contained in the vessels, but not entirely so, for a red colouring matter, apparently of the same nature as that of the blood, is obviously incorporated with the fibres.

Physical properties.

Colour.

Development of muscle. — Valentin and Schwann, who were the first to investigate this point, represented that the muscular fibres are derived from nucleated cells, which coalesce together in rows, and undergo other changes. Nuclei being formed in a soft blastema, are arranged in linear series and become surrounded with delicate envelopes, so as to form a string of cohering cells. (Fig. 50′, ¹.) The cells contain, besides the nuclei, a few detached round granules ; by absorption of their adhering parts, they coalesce into a tube ; and within the tube so produced, the fibrillæ begin to be formed, by deposition and linear arrangement of their elementary particles on its inner surface. The formation of fibrils goes on until they fill up the tube, which after this, according to Schwann, becomes the sarcolemma ; but the last-mentioned point is doubtful, and there is great reason to believe that the sarcolemma is a subsequent formation.

Development.

The nuclei remain for a time in the axis of the growing fibre,—a condition which is persistent in the muscles of insects; but in higher animals they become dispersed among the fibrils, and increased in number, for those seen in the perfect fibre are more numerous than can be accounted for merely by the persistence of the original cell nuclei.

I have seen growing fibres from the fœtal sheep, which were in the condition represented by Schwann, in fig. 50′,[2]; only the granules within were somewhat regularly disposed in transverse lines between the nuclei.

Fig. 50′.*

Henle has suggested that the nucleated cells may first coalesce to form an axis, round which the fibrillæ are deposited from without,—and that the sarcolemma is then formed on the surface of the fibre, whilst the axis disappears from its centre.

In a recent memoir on the development of muscular fibre in mammalia,† Mr. Savory gives a description of the process corresponding in certain respects with that given by Henle; but he finds that free nuclei and not cells are immediately concerned in the production of the muscular fibres. To form a fibre a number of nuclei, finally acquiring an oval figure, arrange themselves in a single row, in which they are closely packed side by side, with their long axes lying transversely. The blastema, at first irregularly aggregated, becomes arranged in two thin, pellucid bands, bordering the fibre, and bounding the extremities of the nuclei. The fibre next lengthens by assumption of new material, and the nuclei withdraw farther from each other. The lateral bands

* Fig. 50′. Development of muscular fibre after Schwann. 1, 2, 3, are fibres from the dorsal muscles of a fœtal pig, 3½ inches long. 3, represents the fibre (2) after the action of acetic acid. 4, 5, 6, are fibres from the muscles about the humerus of a fœtal pig five inches long. 5, shows the nuclei attached to the wall of the tube; in 4 and 6 is also seen the gradual deposition of the substance from which the fibrillæ are formed on the inner surface of the tubular fibre (magnified about 450 diameters).

† Phil. Trans. 1855.

fall in, and ultimately coalesce in the intervals between the nuclei, so that the fibre becomes much thinner. The nuclei then decay and disappear, and striæ become visible within the margin of the fibre, the fibre subsequently increases in size by means of fresh nuclei which attach themselves to its exterior, become invested with blastema, and are finally blended with the fibre.

The fibres are at first smaller than at subsequent periods, as has been noticed by Leeuwenhoek and most succeeding observers. In the embryo frog, at the earliest period that I could detect a muscular structure, the fibres seemed almost to consist of single fibrillæ, connected with remnants of coalesced and apparently flattened cells and nuclei; at a later stage the number of fibrils in the fibres had increased, and the fibres were of course thicker.

It is well known that the muscular system, after acquiring its full development, is subject to frequent variations of bulk in the progress of life, and it still remains a question whether in such cases the number of the muscular fibres is increased by new formation and diminished by absorption, or whether the variation of the whole muscle is due to an increase or diminution of the bulk of the individual fibres while their number remains unaltered.

Not regenerated.

As far as can be concluded from observations and experiments that have hitherto been made on the subject, the muscular tissue is not regenerated in warm-blooded animals. It is true that when a portion of muscle is cut out the breach will heal, but the loss of substance is not repaired by new-formed muscular tissue.

Vital properties.

Vital properties of muscle.—The muscular tissue possesses a considerable degree of *sensibility*, but its characteristic vital endowment, as already said, is *irritability* or *contractility*, by which it serves as a moving agent in the animal body.

Sensibility of muscle.

Sensibility.—This property is manifested by the pain which is felt when a muscle is cut, lacerated, or otherwise violently injured, or when it is seized with spasm. Here, as in other instances, the sensibility belongs, properly speaking, to the nerves which are distributed through the tissue, and accordingly when the nerves going to a muscle are cut, it forthwith becomes insensible. It is by means of this property, which is sometimes called the "muscular sense," that we become conscious of the existing state of the muscles which are subject to the will, or rather of the condition of the limbs and other parts which are moved through means of the voluntary muscles, and we are thereby guided in directing our voluntary movements towards the end in view. Accordingly, when this muscular sense is lost, while the power of motion remains,—a case which, though rare, yet sometimes occurs,—the person cannot direct the movements of the affected limbs without the guidance of the eye.

Contractility or irritability.

Irritability or Contractility.—The merit of distinguishing this property of the animal body from sensibility on the one hand, and from mere mechanical phenomena on the other, is due to Dr. Francis Glisson, a celebrated English physician of the seventeenth century; but irritability, according to the view which he took of it, was supposed to give rise to various other phenomena in the animal economy besides the

visible contraction of muscle, and his comprehensive acceptation of the term has been adopted by many succeeding authorities, especially by writers on pathology. Haller, in his use of the term irritability, restricted it to the peculiar property of muscle.

Stimuli, how applied.

In order to cause contraction, the muscle must be excited by a stimulus. The stimulus may be applied immediately to the muscular tissue, as when the fibres are irritated with a sharp point; or it may be applied to the nerve or nerves which belong to the muscle; in the former case, the stimulus is said to be "immediate," in the latter, "remote." The nerve does not contract, but it has the property, when stimulated, of exciting contractions in the muscular fibres to which it is distributed, and this property, named the "vis nervosa," is distinguished from contractility, which is confined to the muscle. Again, a stimulus may be either directly applied to the nerve of the muscle, as when that nerve is itself mechanically irritated or galvanised; or it may be first made to act on certain other nerves, by which its influence is, so to speak, conducted in the first instance to the brain or spinal cord, and then transferred or reflected to the muscular nerve.

Immediate and remote stimuli: direct and indirect.

Kinds of stimuli.

The stimuli to which muscles are obedient are of various kinds; those best ascertained are the following, viz.: 1. Mechanical irritation of almost any sort, under which head is to be included sudden extension of the muscular fibres. 2. Chemical stimuli, as by the application of salt or acrid substances. 3. Electrical; usually by means of a galvanic current made to pass through the muscular fibres or along the nerve. 4. Sudden heat or cold; these four may be classed together as *physical stimuli*. Next, *mental stimuli*, viz.: 1. The operation of the will, or volition. 2. Emotions, and some other involuntary states of the mind. Lastly, there still remain exciting causes of muscular motions in the economy, which, although they may probably turn out to be physical, are as yet of doubtful nature, and these until better known may perhaps without impropriety be called *organic stimuli;* to this head may be also referred, at least provisionally, some of the stimuli which excite convulsions and other involuntary motions which occur in disease.

Physical and mental.

Organic.

Excitation by electric current.

In regard to electrical stimuli it must be observed that, in order to produce contraction of a muscle by excitement of its nerve, the electric current must pass some way, however short, along the nerve; if it merely cross the nerve diametrically it will have no effect. So long as a current passes equably along the nerve there is no excitement of the muscle, for this takes place only when the current begins or ceases, or undergoes a change (whether by increase or diminution) of its intensity. In a vigorous muscle contraction is always excited both on closing and breaking the electric circuit; in other words, both when the current begins, and when it ceases; but in a partially exhausted muscle there may be a difference according to the direction of the current. In the latter case when the current is *direct*, that is, when it passes along the nerve in a direction towards the muscle, contraction is excited on closing the circuit, and then only; but when the current is *inverse*, or directed towards the root of the nerve, the effect takes place only on breaking the circuit.

All muscles are not indifferently obedient to the same stimuli. The difference in their subjection to the will has been already mentioned, and there are other cases, though of less note, in which they differ either in their capability of being excited by a certain kind of stimulus, or in the readiness with which they are affected by it.

Condition of a muscle during contraction.

Phenomena of muscular contraction.—A muscle when in action is shortened, or exhibits a tendency to shorten; at the same time it swells in the middle and becomes firm and rigid to the feel. This condition, after continuing for a longer or shorter time, is succeeded by relaxation. Careful experiments have proved that the muscle undergoes no change of volume during its action, the shrinking in one direction being compensated by the enlargement in another.

The fibres of a muscle, which has been called into action, exhibit in certain circumstances a series of zig-zag bendings, and from this appearance, which was noticed by Dr. Hales, and more recently by Prevost and Dumas, it was inferred that the shortening of the muscle was owing to its fibres assuming such serpentine flexures, in which condition of course their extremities are more approximated. But from a more careful investigation of this phenomenon there is reason to believe that the bent condition of the fibre is not coincident with its actual contraction. In the act of contracting, the fibre becomes shorter and thicker, but does not fall out of the straight line; on being subsequently relaxed, however, it is thrown into serpentine plicæ, and remains so until its extremities, which had been brought nearer by contraction, are drawn out again by some stretching force. Moreover, it may readily happen that fibres which are not in action may be corrugated by the contraction of others running along with them.

Minute changes.

During contraction the individual fibres are thickened or swollen out at short intervals, and with a high power of the microscope it may be seen that in the swollen parts the transverse lines characteristic of the striped fibre are approximated, whilst in the intermediate narrower portions they are more than the mean distance apart. The commencement and progress of this change has been carefully studied by Mr. Bowman, on detached muscular fibres of the crustacea. According to his observations, the approximation of the striæ and the simultaneous swelling, begin at isolated points along the fibre; at first not affecting its whole diameter, but being confined to one side and causing a series of bulgings on the margin. From its point of commencement the contraction spreads into the fibre equally in all directions, its progress not conforming to the arrangement either of the fibrillæ or the transverse stripes; and accordingly the latter may be closely approximated on one side of the fibre, while on the other side they are at their usual distance. Between the contracting parts the fibre is narrower, and its cross striæ further apart. These contractions, however, do not remain stationary, but travel along the fibre; and parts which are shortened and swollen at one moment, become lengthened and narrowed the next, being drawn out by contraction of the neighbouring portions,—unless, indeed, the ends of the fibre are free, and offer no resistance to their approximation; for in that case the contraction advancing to a fresh portion, merely causes a further approach of the ends, and for want of a fixed resistance cannot draw out the parts previously contracted. The contractions continuing to oscillate along the fibre from end to end, gradually involve its whole thickness; they increase in number and extent, and the ends of the fibre if free to move are drawn nearer and nearer, until at last it is greatly reduced in length, its motions cease, and it remains in that state of rigidity which affects all muscles sooner or later after death.

Oscillating contractions of the fibres.

It thus appears that in the movements of detached portions of muscle, a multitude of partial contractions oscillate to and fro along each fibre, and from the appearances presented by muscular fibres

which have been ruptured by tetanic spasm, Mr. Bowman is led to infer that the ordinary contraction of muscles in the living body takes place in this way. He concludes that "the sustained active contraction of a muscle is an act compounded of an infinite number of partial and momentary contractions, incessantly changing their place, and engaging new portions in succession."

Muscular sound.

This view strikingly accords with the fact that a remarkable sound is heard when the ear is applied over a muscle during its action. This "muscular sound," which was compared by Dr. Wollaston to the distant noise of carriage-wheels, has a thrilling or vibratory character, and may with great probability be ascribed to the friction of the oscillating fibres against each other. Indeed, Roger, who first seems to have specially called attention to the phenomenon, and, at a later period, Dr. Wollaston, were led by it to form conclusions respecting the state of the contracting fibres agreeing very nearly with what Mr. Bowman has since proved by actual inspection. Dr. Wollaston inferred that the sustained effort exerted by a muscle acting under the impulse of the will, consists in reality of a great number of contractions repeated at extremely short intervals, and excited by a succession of distinct impulses; and Roger supposed that the "susurrus," as he names the sound, is caused by a sort of peristaltic motion of the fibrils.*

Rise of temperature.

A rise of temperature takes place in a muscle during its contraction. Breschet and Becquerel have found that this may amount to one or two degrees of Fahrenheit's scale in the voluntary contraction of the muscles of the human arm, and Matteucci, by experimenting on the detached limbs of frogs, has shown that the development of heat is not to be ascribed merely to some modification of the circulation of the blood in the muscle, but that it more probably depends on oxidation of its substance.

Chemical changes.

Muscular contraction being attended with a development of force involves a waste or chemical change of part of the material employed. The special nature of this change is not yet fully ascertained, but there is sufficient evidence to show that some of the constituents of the muscle undergo oxidation.

Electrical phenomena.

It remains briefly to notice the electrical phenomena which accompany muscular contraction. When a muscle of a recently killed frog is brought into connection with the ends of a very delicate galvanometer, so that one extremity of the latter touches the outer surface of the muscle, and the other a cross section made through its fibres, the needle will deviate so as to indicate an electric current passing along the wire from the surface of the muscle to its cross section. If both ends of the galvanometer touch points in the length of the muscle equidistant from its middle, no effect ensues, but if one point of contact be farther than the other from the middle, a current will pass along the wire from the nearer to the more distant point. The same results are obtained with a small shred or fasciculus of the muscle. The phenomenon described is called "the muscular current," and is supposed to

* Josephi Lud. Roger, De perpetua fibrarum muscularium palpitatione, &c. Gottingae, 1760. Roger supposed that the oscillation of the fibrils and accompanying sound are constant, but that they are greatly increased during contraction of the muscle. See also observations by Remak, on the oscillatory contractions of muscular fibres after death, in Müller's Archiv. 1843, p. 182.

indicate a state of electric polarity in the particles of the muscle, probably caused by chemical changes going on in its substance. When contraction is excited the galvanometer needle deviates in an opposite direction to that caused by the current of the quiescent muscle, and Du Bois Reymond ascribes this effect to a cessation or diminution of the ordinary muscular current during the action of the muscle, so that it is overcome by a current in the opposite direction, caused by the polarisation of the platinum plates of the galvanometer. Matteucci on the other hand maintains that at the moment of contraction an independent discharge of electricity takes place in a direction opposite to that of the "muscular current." Whatever be the right explanation, it is clear that an *electric change* occurs during the contraction of a muscle, and the fact may also be made apparent by the following experiment of Matteucci which it is easy to repeat. Detach the posterior limb of a frog, dissect out the sciatic nerve as far as the knee, leaving it connected with the leg, and cut away the thigh; then lay this nerve across the denuded muscles of the remaining thigh or of the thigh of another recently-killed frog, insulated on a plate of glass, and excite contractions in the muscles of the thigh by mechanical or galvanic irritation of their nerves. Every time this is done, contractions simultaneously occur in the detached leg from electric stimulation of its nerve by the contracting muscles on which it is laid. A frog's nerve and muscles may be excited in the same manner by the contracting muscles of a warm-blooded animal.

The thermal, chemical, and electrical phenomena together with the development of mechanical force, which manifest themselves during muscular action, are probably all correlated and mutually dependent; for further information concerning them the reader is referred to general treatises on Physiology and to the special sources mentioned below.*

Theories of muscular contraction.

Much ingenious speculation has been bestowed in endeavouring to explain the immediate or proximate cause of muscular contraction, but on this point we really know nothing more than that the contraction depends on a disposition which the muscular substance has to shrink in a particular direction, when acted on by stimuli. From what has been said, we must also conclude that it is between the minutest and to us invisible molecules that this tendency to approximation is exerted: thus, the contraction spreads through a striped fibre without reference to the arrangement of its visible elements; it occurs in the apparently amorphous contractile substance of the amœba and other creatures of similar, low organisation; and the embryo heart contracts whilst its tissue is yet but a mass of cells, without apparent fibres. It is plain, therefore, that any hypothesis or explanation which assumes the visible mechanical construction of a muscular fibre as a necessary condition of the contraction of its substance, must fall to the ground; and although in the higher animals the contractile substance is fashioned into fibres, more or less complex in structure, we can conceive it to retain its peculiar property, when reduced to smaller masses, and existing under different forms; and it is with this understanding as to the nature

* Matteucci's several Memoirs on Electro-physiology in the Philosophical Transactions, and Abstract of Du Bois Reymond's Researches on Animal Electricity, translated by Dr. B. Jones, 1852.

of the material endowed with vital contractility, that we ascribe the motion of cilia to that property.

Relation of contractility to the nervous system.

It has been keenly disputed since the days of Haller, whether the contractility of muscle is a property inherent in its substance,—a "vis insita," as Haller believed,—or is derived from the nerves, and, as it were, conferred by them on the muscular fibre. To discuss at length the arguments of this controversy, would here obviously be out of place ; I shall therefore only remark that the former view is the more simple, and is that to which we are naturally led on reflecting that muscle is of a different substance from nerve,—that wherever muscle is found it manifests the contractile property,—and that, on the other hand, a nerve is never seen to contract in any circumstances. Nor is the straightforward view originally adopted by Haller in any way shaken by the experimental inquiries that have been instituted in order to determine the question,—that is, when the conditions of these experiments are duly attended to, and their results fairly appreciated. But, admitting that irritability is not *derived* from the nervous system, it has been held by some that this property can be *excited* only through the medium of the nerves, and that a stimulus apparently applied to the muscular fibres really acts on the fine nervous filaments intermixed with them ; others, again, think as Haller did, that although for obvious reasons muscles are generally, and in voluntary acts always, stimulated through the intervention of the nerves, yet that stimuli may also act directly on the muscular fibre. The correctness of the latter opinion can scarcely now be doubted, since, in addition to what has been hitherto urged in its favour, we have now what may be considered as direct experimental evidence of its truth ; for Mr. Bowman has observed, by means of the microscope, that contractions take place in small insulated fragments of muscular fibre, to all appearance free from nerves,—and further, that a minute foreign body, such as a hair or a particle of dust, when it touches a fibre, will cause a contraction which begins at the point of contact and is limited to its immediate vicinity, so as to show plainly that it is caused by the mechanical irritation of the particle acting directly on the fibre.

Effect of exercise on muscles.

Forcible and prolonged action of the voluntary muscles is followed by a sense of fatigue, and the immediate effect of muscular contraction is to exhaust irritability. But this is recovered again by repose ; and the exercise of muscles, provided it alternates with due intervals of rest, tends to maintain their power and promote their nutrition and growth. Indeed, we see examples, in some cases, of an overgrowth or hypertrophy of the muscular tissue from increased demands on its activity ; as in the instance of the parietes of the heart and urinary bladder, when an impediment has long existed to the free issue of the fluids which these muscular organs are called on to propel. On the other hand the muscles become wasted, and their functional activity is impaired, by disuse.

Tonicity.

Tonicity or tonic contraction.—Although in muscles generally contraction is succeeded by complete relaxation, there are various muscles which, after apparently ceasing to contract, remain in a state of tension, and have still a certain tendency to approximate their points of attachment, although this tendency is counterbalanced by antagonist muscles, which are in the same condition, and the moveable part is thus maintained at rest. This condition of muscles is named "tonicity," or "the tonic state." It is no doubt a species of contraction, as well as the more conspicuous and powerful action with which it may alternate ;

but it is employed merely to maintain equilibrium, not to cause motion, and it is not temporary but enduring,—continuing during sleep, when volition is in abeyance, and occasioning no fatigue. It appears to be excited through the medium of the nerves, though independently of the will, for when the nerves are cut it ceases, and then the muscles really become flaccid: the stimulus which acts on the nerves is not known. The condition of the muscular fibres in this tonic state has scarcely yet been ascertained with certainty, but Mr. Bowman is disposed to think from observations he has made, that the cross striæ are approximated uniformly throughout the whole length of the fibre.

Relation of force exerted to degree of contraction.

Force of contraction.—It has been shown by Schwann, that the force exerted by a contracting muscle follows the same law as that produced by the shrinking of a stretched elastic substance; that it is greatest at the commencement of contraction, and diminishes as the muscle shortens, becoming equal to nothing when the muscle has contracted to its utmost degree. From the nature of their connections in the living body, however, the muscles—at least, those of locomotion—are not permitted to shorten to their extreme point of contraction; it is estimated that the shortening seldom amounts to more than a third of their length, but it may go greatly beyond this when they are freed from their attachments. Other things being equal, the force exerted will be proportionate to the number of contracting fibres, and therefore greater in a thicker muscle. But the force varies with the state of nutrition of the muscle, with its previous vigour or exhaustion, and also according to the intensity of the stimulus applied to it. The last-mentioned circumstance is indeed one of the most wonderful provisions in the constitution of our frame, for by an effort of the will, we can not only call a muscle into exercise, but within certain limits regulate with the utmost nicety the force exerted by it. It may be further remarked, that the force which a living muscle is able to exert, is much greater than that which the same muscle is able mechanically to sustain after death; a dead muscle, indeed, is torn across by a very moderate force.

Velocity of contraction.

Velocity and order of contractions.—Contraction for the most part takes place with considerable velocity, but there are differences in this respect; we see examples of extreme rapidity in the motion of the eyelids, and of slowness in the comparatively sluggish contractions of the alimentary canal and bladder. In some involuntary muscles the contraction varies also in other characters. In the muscular coats of certain hollow viscera, such as the alimentary canal, it travels along, so to speak, narrowing different parts of the cavity in succession; this is named "peristaltic," or "vermicular" contraction. In the heart the contraction is continually and regularly repeated after short and equal intervals of repose, and this is termed "rhythmic" contraction.

Peristaltic and rhythmic contractions.

Conditions of muscular action.

Conditions necessary to muscular action.—The necessity of a stimulus to the muscular fibre has been already mentioned. To this must be added a certain limit of temperature and the due nutrition of the muscle, both of which conditions have greater influence in warm-blooded animals. It is known that if the supply of nutrient material be cut off from a muscle by arresting the flow of blood into it, its contractility will be impaired, and soon extinguished altogether, but will, after a time, be recovered again if the supply of blood be restored. This experiment has been often repeated on dogs since the time of Nicholas Stenonis, to whom its first performance is generally ascribed,

and the same effect, though less speedy and less marked, has been observed to result in cold-blooded animals, by Engelhardt and Valentin. The influence of the blood supplied to muscles in maintaining their contractility has been strikingly shown in some recent experiments by Dr. Brown-Séquard, who has succeeded in restoring muscular contractility in the bodies both of man and animals some time after death and after it had become to all appearance extinct, by injecting into the vessels arterial blood deprived of its fibrin, or defibrinated venous blood previously reddened by exposure to the air. In warm-blooded animals in which the nutritive process is more active, and the expenditure of force more rapid, the maintenance of irritability is more closely dependent on the supply of blood and the influence of oxygen, so that it sooner fails after these are cut off.

Duration of irritability after death.

Duration of irritability after death.—In accordance with what has just been stated, it is known that while the muscles of man and quadrupeds all cease to be irritable within a few hours after death, and those of birds still sooner, the muscular irritability will remain in many reptiles and fish, even for days after the extinction of sensation and volition, and the final cessation of the respiration and circulation,—that is, after systemic death. A difference of the same kind is observed among warm-blooded animals in different conditions; thus irritability endures longer in new-born animals than in those which have enjoyed respiration for some time and are more dependent on that function; and in like manner it is very lasting in hybernating animals killed during their winter sleep.

But the duration of this property differs also in different muscles of the same animal. From the researches of Nysten, it appears that in the human body its extinction takes place in the following order, viz.: 1, the left ventricle of the heart; 2, the intestines and stomach; 3, the urinary bladder; 4, the right ventricle; in these generally within an hour; 5, the gullet; 6, the iris; 7, the voluntary muscles, *a* of the trunk, *b*, of the lower, and *c*, the upper extremities; 8, the left auricle, and 9, the right auricle of the heart, which last was on this account styled by Galen the "ultimum moriens." In one case Nysten observed the right auricle to continue irritable for sixteen hours and a half after death.

The time of duration is affected by the mode of death. Thus the irritability is said to be almost wholly and immediately extinguished by a fatal stroke of lightning, and to disappear very speedily in the bodies of persons stifled by noxious vapours, such as carbonic acid, and especially sulphuretted hydrogen. In like manner certain causes acting locally on muscles accelerate the extinction of their irritability; among these causes we may especially enumerate exposure to air, immersion of the muscle in cold water, and the application of watery solution of opium. It may be observed, however, that the alleged effect of external agents, whether acting locally or generally, on the duration of irritability, requires further investigation.

Cadaveric rigidity.

Rigor mortis.—The "cadaveric rigidity," or stiffness of the body, which ensues shortly after death, is a phenomenon depending on the muscles, which become fixed or set in a rigid state, so as to resist flexion of the joints. The rigidity almost invariably begins in the muscles of the lower jaw and neck, then invades those of the trunk, and afterwards those of the limbs,—the arms usually before the legs. After persisting for a time, it goes off in the same order. It usually comes on within a few hours after death; in some cases it has been

observed to begin within ten minutes (Sommer), and in others not till sixteen or eighteen hours; and the later its access, the longer is its endurance. The rigidity comes on latest, attains its greatest intensity, and lasts longest in the bodies of robust persons, cut off by a rapidly fatal disease, or suddenly perishing by a violent death; in such cases it may last six or seven days. On the other hand, it sets in speedily, is comparatively feeble, and soon goes off in cases where the body has been much weakened and emaciated by lingering or exhausting diseases; also in newborn infants, and in the muscles of animals that have been hunted to death. It seems thus to be affected by the previous state of nutrition of the muscles. Dr. Brown-Séquard, in the experiment already referred to, found that the injection of blood, in restoring the irritability of muscles after death, at the same time completely removed the rigidity with which they had become affected. Destruction of the nervous centres does not prevent the occurrence of rigidity, nor are the muscles of paralysed limbs exempted from it, provided their nutrition has not been too deeply affected. The muscles in stiffening may cause a slight change in the position of the parts to which they are attached; thus the jaw is drawn up, the fore arm and fingers slightly bent, and the thumb turned inwards on the palm.

The immediate cause of the muscular rigidity is doubtful: some conceive it to be an effect of vital contraction—the last effort of life as it were; some regard it as the result of coagulation of blood in the capillaries, which, however, seems a scarcely admissible cause; others ascribe it to an induration of the fibrin of the muscular tissue, like what occurs in the buffy coat of the blood; but, in truth, the nature of the change is not sufficiently understood. Its general accession is an unequivocal sign of death.

NERVOUS SYSTEM.

General remarks.

Of the functions performed through the agency of the nervous system, some are entirely corporeal, whilst others involve phenomena of a mental or psychical nature. In the latter and higher class of such functions are first to be reckoned those purely *intellectual operations*, carried on through the instrumentality of the brain, which do not immediately arise from an external stimulus, and do not manifest themselves in outward acts. To this class also belong *sensation* and *volition*. In the exercise of sensation the mind becomes conscious, through the medium of the brain, of impressions conducted or propagated to that organ along the nerves from distant parts; and in voluntary motion a stimulus to action arises in the brain, and is carried outwards by the nerves from the central organ to the voluntary muscles. Lastly, *emotion*, which gives rise to gestures and movements varying with the different mental affections which they express, is an involuntary state of the mind, connected with some part of the brain, and influencing the muscles through the medium of the nerves.

The remaining functions of the nervous system do not necessarily imply any participation of the mind. In the production of those movements, termed *reflex*, *excited*, or *excito-motory*, a stimulus is carried along afferent nerve-fibres to the brain or spinal cord, and is then transferred to efferent or motor nerve-fibres, through which the muscles are excited to action; and this takes place quite independently of the will, and may occur without consciousness. The motions of the heart, and of other internal organs, as well as the invisible changes which occur in secretion and nutrition, are in a certain degree subject to the influence of the nervous system, and are undoubtedly capable of being modified through its agency, though, with regard to some of these phenomena, it is doubtful how far the direct intervention of the nervous system is necessary for their production. These actions, which are all strictly involuntary, are, no doubt, readily influenced by mental emotions; but they may also be affected through the nerves in circumstances which entirely preclude the participation of the mind.

Central organs and nerves.

The nervous system consists of a *central part*, or rather a series of connected *central organs*, named the *cerebro-spinal axis*, or *cerebro-spinal centre*; and of the *nerves*, which have the form of cords connected by one extremity with the cerebro-spinal centre, and extending from thence through the body to the muscles, sensible parts, and other organs placed under their control. The nerves form the medium of communication between these distant parts and the centre. One class of nervous fibres, termed *afferent* or *centripetal*, conduct impressions towards the centre, — another, the *efferent* or *centrifugal*, carry motorial stimuli from the centre to the moving organs. The nerves are, therefore, said to be internuncial in their office, whilst the central organ receives the impressions conducted to it by the one class of nerves, and imparts stimuli to the other,—rendering certain of these impressions cognisable to the mind, and combining in due association, and towards a definite end, movements, whether voluntary or involuntary, of different and often of distant parts.

Ganglia.

Besides the cerebro-spinal centre and the nervous cords, the nervous system comprehends also certain bodies named *ganglia*, which are connected with the nerves in various situations. These bodies, though of much smaller size and less complex nature than the brain, agree, nevertheless, with that organ in their elementary structure, and to a certain extent also in their relation to the nervous fibres with which they are connected; and this correspondence becomes even more apparent in the nervous system of the lower members of the animal series. For these reasons, as well as from evidence derived from experiment, but which is of a less cogent character, the ganglia are regarded by many as nervous centres, to which impressions may be referred, and from which motorial stimuli may be reflected or emitted; but of local and limited influence as compared with the cerebro-spinal centre, and operating without our consciousness and without the intervention of the will.*

* It must be confessed that the recent progress of inquiry is not favourable to this view of the office of the ganglia. From the researches of Dr. Augustus Waller it would appear probable that these bodies exert some influence over the nutrition of the nerve-fibres connected with them, and serve to maintain the structural integrity of these fibres; for it has been found that when a ganglionic nerve is cut across in a living animal, the part beyond the section after a time becomes atrophied, while the part connected with the ganglion retains its integrity.

Cerebro-spinal and ganglionic nerves.

The nerves are divided into the *cerebro-spinal*, and the *sympathetic* or *ganglionic* nerves. The former are distributed principally to the skin, the organs of the senses, and other parts endowed with manifest sensibility, and to muscles placed more or less under the control of the will. They are attached in pairs to the cerebro-spinal axis, and like the parts which they supply are, with few exceptions, remarkably symmetrical on the two sides of the body. The sympathetic or ganglionic nerves, on the other hand, are destined chiefly for the viscera and blood-vessels, of which the motions are involuntary, and the natural sensibility is obtuse. They differ also from the cerebro-spinal nerves in having generally a greyish or reddish colour, in their less symmetrical arrangement, and especially in the circumstance that the ganglia connected with them are much more numerous and more generally distributed. Branches of communication pass from the spinal and several of the cerebral nerves at a short distance from their roots, to join the sympathetic, and in these communications the two systems of nerves mutually give and receive nervous fibres.

White and grey nervous matter.

The nervous system is made up of a substance proper and peculiar to it, with inclosing membranes, areolar tissue, and blood-vessels. The *nervous substance* has been long distinguished into two kinds, obviously differing from each other in colour, and therefore named the *white*, and the *grey* or *cineritious*.

CHEMICAL COMPOSITION.

Chemical composition.

The information we possess respecting the chemical composition of nervous matter is for the most part founded on analyses of portions of the brain and spinal cord ; but the substance contained in the nerves, which is continuous with that of the brain and cord, and similar in physical characters, appears also, as far as it has been examined, to be of the same general chemical constitution. No very careful comparative analysis has yet been made of the grey and white matter, to say nothing of the different structural elements of the nervous substance ; and indeed it must be remembered, that, in portions of brain subjected to chemical examination, capillary blood-vessels, and perhaps other accessory tissues, are mixed up in greater or less quantity with the true nervous matter, and must so far affect the result.

The nervous matter may be said to consist of albumen dissolved in water, and combined with fatty principles and salts. The water, which forms four-fifths of the whole cerebral substance, may be removed by immersion in alcohol and evaporation. When the solid matter which remains, after removal of the water, is treated with ether and hot alcohol, the fatty compounds are extracted from it by these menstrua, and there remains a mixture of coagulated albumen and salts with a small amount of accessory tissues, chiefly vessels.

According to Vauquelin, the human brain contains in one hundred parts, water 80, albumen 7, white fat 4·55, red fat 0·7, osmazome 1·12, phosphorus 1·5, acids, salts, and sulphur 5·15. Of the fat, cholesterin forms a large part. The remainder may, according to Couerbe, be resolved into, 1. *Cerebrot*, an unsaponifiable and difficultly fusible fat like cholesterin; 2. *Eleencephol*, a reddish oil which readily dissolves the other cerebral fats; 3. *Cephalot;* and 4. *Stearo-conot*, two solid saponifiable fats of a yellow colour, differing in fusibility and in their solubility in ether. Couerbe states, that these four fatty compounds contain, in addition to the usual elements of such substances, also nitrogen, sulphur, and phosphorus.

Frémy, who has since investigated the subject, represents the cerebral substance as consisting of 80 per cent. of water, 7 of albumen, 8 of osmazome and salts, and 5 of fatty constituents. These last are, 1. *Cerebric acid*, which is the most abundant; 2. *Cholesterin;* 3. *Oleophosphoric acid;* and 4. Olein, Margarin, and traces of their acids. Frémy denies that they contain sulphur as a constituent, and he ascribes the presence of that ingredient to an admixture of albumen. He finds that the oleophosphoric acid is a very unstable compound, and that under the influence of slight causes it is readily transformed into phosphoric acid and olein. According to the same inquirer, the fat contained in the brain is confined almost entirely to its white substance, which loses its characteristic white aspect when the fat has been extracted.

The following analysis by Lassaigne represents the relative proportions in the grey and white matter:—

	Grey.	White.
Water	85·2	73·0
Albuminous matter	7·5	9·9
Colourless fat	1·0	13·9
Red fat	3·7	0·9
Osmazome and lactates	1·4	1·0
Phosphates	1·2	1·3
	100·0	100·0

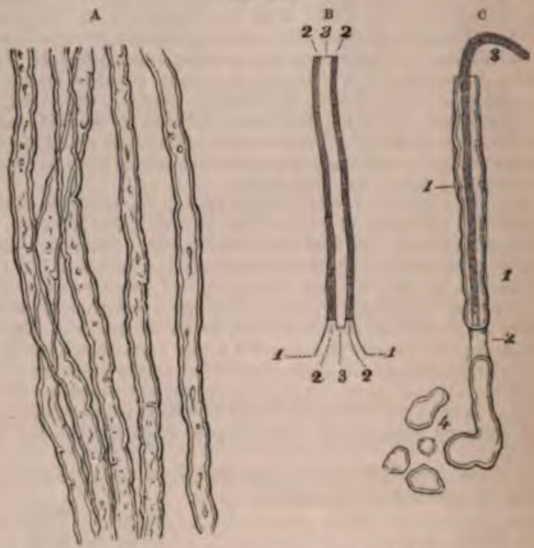
The spinal cord and nerves yield the same constituents as the brain; but the cord is said by Vauquelin to contain a larger proportion of fat; and, according to L'Heritier, the nerves contain more albumen, and less of solid, but more of soft fat than the brain.

STRUCTURAL ELEMENTS.

Elementary structure.

When subjected to the microscope, the nervous substance is seen to consist of two different structural elements, viz. *fibres*, and *cells* or *vesicles*. The fibres are found universally in the nervous cords, and they also constitute the greater part of the nervous centres; the cells or vesicles on the other hand are confined in a great measure to the cerebro-spinal centre and the ganglia, and do not exist in the nerves properly so called, unless it be at their peripheral

Fig. 51′.*



* A. Tubular nerve-fibres, showing the sinuous outline and double contours.

B. Diagram to show the parts of a tubular fibre, viz. 1, 1, *membranous tube*. 2, 2, *white substance* or *medullary sheath*. 3, *axis* or *primitive band*.

C. Figure (ideal) intended to represent the appearances occasionally seen in the tubular fibres. 1, 1, membrane of the tube seen at parts where the white substance has separated from it. 2, a part where the white substance is interrupted. 3, axis projecting beyond the broken end of the tube. 4, part of the contents of the tube escaped.

expansions in some of the organs of special sense; they are contained in the grey portion of the brain, spinal cord, and ganglia, which grey substance is in fact made up of these vesicles intermixed in many parts with fibres, and with a variable quantity of granular or amorphous matter.

In further pursuing the subject, we shall first examine the fibres and cells by themselves, and afterwards consider the structure of the parts which they contribute to form, viz. the cerebro-spinal organs, the ganglia, and the nerves.

The fibres are of two kinds; the *tubular* or *white*, and the *gelatinous* or *grey*: the former are by far the most abundant; the latter are found principally in the sympathetic nerve, but are known to exist also in many of the cerebro-spinal nerves. Two kinds of fibres.

*The Tubular Fibres.**—These form the white part of the brain, spinal cord, and nerves. When collected in considerable numbers, and seen with reflected light, the mass which they form is white and opaque. Viewed singly, or few together, under the microscope, with transmitted light, they are transparent; and if quite fresh from a newly-killed animal, and unchanged by cold or exposure, they appear as if entirely homogeneous in substance, like threads of glass, and are bounded on each side by a simple and usually gently sinuous outline. Their size differs considerably even in the same nerve, but much more in different parts of the nervous system; some being as small as the $\frac{1}{12000}$th and others upwards of the $\frac{1}{1500}$th of an inch in diameter, and the same fibre may change its size in different parts of its course. Very speedily after death, and especially on exposure to the action of water, these seemingly homogeneous fibres become altered; and it is when so altered that they are commonly subjected to examination, as represented in fig. 51′, A. In particular instances, and in favourable circumstances, it may be discovered that the fibre is composed of a fine membranous tube, inclosing a peculiar soft substance, and that this contained substance itself is distinguishable into a central part placed like a sort of axis in the middle of the tube, and a peripheral portion surrounding the axis, and occupying the space between it and the tubular inclosing membrane. In the annexed ideal plan (fig. 51′, B), the *membranous tube* is

Tubular fibres.

Size.

Structure.

* Also named "white fibres" and "nerve-tubules:" I prefer the term "tubular fibres," first used, so far as I know, by Dr. Todd.

marked 1, 1: the central part, marked 3, was named *cylinder axis* by Purkinje, who considered it to be identical with the structure previously described by Remak under the name of the *primitive band* (fibra primitiva); the matter surrounding it, marked 2, 2, is supposed to be the chief cause of the whiteness of the brain and nerves, and it was accordingly named the *white substance* by Schwann, and by others, though less appropriately, the *medullary sheath*. It is this last-mentioned substance which undergoes the most marked change on exposure; it then seems to suffer a sort of coagulation or congelation, and when this has taken place, it very strongly refracts the light, and gives rise to the appearance of a shaded border on each side of the nerve-tube (fig. 51′, A and C). This border, though darker than the rest of the tube, is nevertheless translucent, and is either colourless, or appears of a slightly yellowish or brownish tint; it is bounded by two nearly parallel lines, so that the nerve-fibre has then a double contour, and the inner line gradually advances further inwards as the change in the white substance extends to a greater depth. These parallel lines pursue a sinuous course, often with deep and irregular indentations; while straight or curved lines of the same character, occasioned no doubt by wrinkles or creases in the layer of white substance, are frequently seen crossing the tube. By continued exposure, round and irregular spots appear at various points, and at length the contents of the nerve-tube acquire a confusedly granulated aspect.

White substance.

The double contour appears only in fibres of a certain size; in very fine tubes, which become varicose or dilated at intervals, the double line is seen only in the enlargements, and not in the narrow parts between. It often happens that the soft contents of the tube are pressed out at the ruptured extremities, as in fig. 51′, C, 4, and then the round or irregular masses of the effused matter are still surrounded by the double line, which proves that this appearance is produced independently of the membranous tube. So long as this tube is accurately filled by the contained matter, its outline cannot be distinguished; but sometimes, when the white substance separates at various points from the inside of the tube, the contour of the fibre becomes indented and irregular, and then the membrane of the tube may, in favourable circumstances, be discerned as an extremely faint line, running outside the deeply-shaded border formed by the white substance, and taking no part in its irregular sinuosities (fig. 51′, C. 1, 1). The membranous tube may also be distinguished at parts where the continuity of its contained matter is broken in consequence of traction, squeezing, or such like injury of the fibre; in such parts the double line produced by the white substance is wanting, and the faint outline of the membranous tube may be perceived passing over the interruption (2). The

Inclosing membrane; how seen.

fine transparent membrane which forms this tube appears to be quite simple and homogeneous in structure, but it has not yet been demonstrated to exist in the finest fibres of either the peripheral or central nervous system.

The *axis* is situated in, or near, the middle of the nerve-tube, where it may occasionally be seen, on a careful inspection, as a transparent stripe or band, bounded on either side by a very faint even outline, having no share in the sinuosities of the white substance (fig. 51′, c). Axis

The axis seems to be of a more tenacious consistence than the white substance, and may accordingly be sometimes seen projecting beyond it at the end of a broken nerve-tube, either quite denuded, or covered only by the tubular membrane, the intervening white substance having escaped. Although the name of axis-cylinder would seem to imply that it had actually a cylindrical figure, yet this is by no means certain; and whether naturally cylindrical or not, it certainly very generally appears more or less flattened when subjected to examination. One writer (Hannover *) is inclined to think that it is hollow, and that it collapses into a flat band when exposed. This view has been recently advocated by Remak; still it does not seem probable. The axis sometimes appears striated longitudinally, and it has been observed even to split into finer filaments. Others have conceived that the soft matter contained in the nerve-tube is of uniform nature throughout, and that the axis is nothing more than a portion of this substance in the centre, which has remained unchanged whilst the superficial and more exposed part has become coagulated; a supposition difficult to reconcile with the fact that the axis often appears more consistent, at least more tenacious, than the enveloping white substance. It seems on the whole more probable that there is an original difference of material between the central and peripheral part of the nerve-pulp, and that the effect of exposure is to render the difference more conspicuous. Kölliker states that the axis-cylinder consists of "a solid protein compound, differing from common fibrin, and from the fibrin of muscles;" that it is universally present in the nerve-fibres, and may be seen immediately after death without the application of any reagent whatsoever. The nerve-pulp, as already stated, is in its chemical constitution an oleo-albuminous compound; and there seems some reason to think that the oleaginous constitution is represented entirely by the white substance; for whilst water, especially when cold, rapidly produces congelation of that substance, ether on the other hand causes it speedily to disappear as if by solution, and globules of oil afterwards make their appearance both within and without the tube, its remaining contents becoming granular.

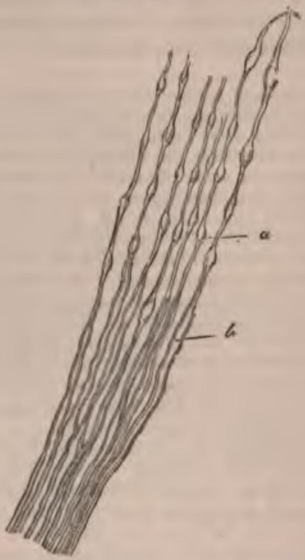
Many of the tubular nerve-fibres, when subjected to the microscope, appear dilated or swollen out at short distances along their length, and contracted in the intervals between the dilated parts. Such fibres have been named *varicose* Varicose fibres.

* Recherches microscopiques sur le Système Nerveux, 1844, p. 29.

Varicose fibres

(fig. 52′). They occur principally in the brain and spinal cord, and in the intra-cranial part of the olfactory, in the optic, and acoustic nerves; they are occasionally met with also in the other nerves, especially in young animals.

Fig. 52′.*



are cylindrical and

These fibres, however, are naturally cylindrical like the rest, and continue so while they remain undisturbed in their place; and the varicose character is occasioned by pressure or traction during the manipulation, which causes the soft matter contained in the nerve-tube to accumulate at certain points, whilst it is drawn out and attenuated at others. Most probably the change takes place before the nerve-pulp has coagulated. The fibres in which it is most apt to occur

of small size.

are usually of small size, ranging from $\frac{1}{12000}$th to $\frac{1}{3000}$th of an inch in diameter; and when a very small fibre is thus affected, the varicosities appear like a string of globules

* Fibres from the root of a spinal nerve.—At *a*, where they join the spinal cord, they are varicose; lower down at *b*, they are uniform and larger.—(Valentin.)

held together by a fine transparent thread. As already remarked, the double contour caused by congelation of the white substance does not appear in the highly-constricted parts. Hannover states that the axis may sometimes be seen running through the varicosities and undergoing no corresponding dilatation.

Neither in their course along the nervous cords, nor in the white part of the nervous centres, have these tubular fibres ever been observed to unite or anastomose together, nor are they seen to divide into branches; it is therefore fair to conclude that, though bound up in numbers in the same nervous cords, they merely run side by side like the threads in a skein of silk, and that they maintain their individual distinctness from one end to the other. They, however, divide in some cases at their peripheral terminations. Tubular fibres do not anastomose.

In certain situations nerve-fibres appear which are destitute of a medullary sheath. These "non-medullated" fibres may be continuous with tubular fibres of the ordinary character, which in their progress lose their white or medullary substance and dark borders. In other cases they may exhibit the non-medullated character throughout, as in the instance of the pale processes of the nerve-cells to be afterwards described. Non-medullated fibres.

Of the Gelatinous Fibres.—These, which have also been named "organic" or "grey" nerve-fibres (fig. 53′), exist in great numbers in the sympathetic nerve, and are also found in many of the cerebro-spinal nerves, but for the most part in much smaller proportion. In both cases they are associated with tubular or white fibres, and they give a grey colour to those nervous cords in which they predominate. There is some doubt as to the real nature of these gelatinous fibres; several anatomists, whose opinion is Gelatinous fibres.

Fig. 53′.*

* Gelatinous nerve-fibres. (*a* and *b* magnified 340 diameters, after Hannover; *c* and *d* after Remak.)

deservedly held in high estimation, denying that they are true nerve-fibres, and maintaining that they belong to the class of enveloping structures, and are allied in nature and office to the fibres of areolar tissue. Size and structure. In their microscopic characters they bear a strong resemblance to the plain muscular fibres, but are of smaller average breadth, their diameter measuring from $\frac{1}{6000}$th to $\frac{1}{4000}$th of an inch. They are flattened, translucent, and apparently homogeneous, or at most faintly granular, with numerous corpuscles resembling cell-nuclei lying on them. Of these nuclei some are round, and many oval or fusiform, lying with their long diameter in the direction of the fibres; many contain one or more nucleoli. These fibres seem to be of rather tenacious consistence, and are difficult to separate from one another; some observers describe them as being sometimes split at their ends into smaller filaments.

Nerve-cells. *Nerve-cells or Nerve-vesicles.*—These, as already mentioned, constitute the second kind of structural elements proper to the nervous system. They are found in the grey matter of the cerebro-spinal centre and ganglions, constituting a principal part of the last-mentioned bodies, and thence often named *ganglionic corpuscles* or *ganglion globules;* they exist also in some of the nerves of special sense at their peripheral expansions. Their structure; The most characteristic form in which the nerve-cells present themselves, is that of a vesicle, constructed of a fine simple, transparent cell-membrane, filled with granular matter, and containing a vesicular nucleus, with one or more nucleoli. The cell-membrane may be demonstrated easily in nerve-cells from the ganglia, but only with great difficulty in those from the central organs, whilst in the smallest corpuscles its existence is a matter of inference only. They differ greatly from one another in size; some being scarcely larger than a human blood-corpuscle, others $\frac{1}{300}$th of an inch or upwards in diameter. size and figure. The greater number are spheroidal in figure, especially those found in the ganglia (fig. 54′, A, *a*, *b*), but they are often more or less angular, oblong or irregular (*c*, *d*) especially when they have been closely packed; and they are liable, too, to become altered and distorted in shape, in the process of extracting and insulating them. But many of the nerve-cells, especially those from the grey matter of the spinal cord and certain parts of the encephalon, present a very remarkable modification of figure, being drawn out at one or more points of their circumference

into long filamentous processes (fig. 55′); and these nerve-cells, like other nucleated cells which present this peculiarity, Caudal process.

Fig. 54′.*

are usually named "caudate;" or, according to the number of processes they present, uni- bi- and multi-polar; terms obviously ill-chosen, but rendered current by frequent use. Many of them are of a pyriform shape, with their small end produced into a slender process either simple or branched at its extremity (fig. 55′, *a*, *b*); others send out several such processes from different points. These processes are formed of extensions of the cell-membrane with its inclosed granular matter, and have a corresponding delicacy of structure, so that they frequently break off at a short distance from the vesicle; they are described by several observers as being prolonged into the nerve-fibres, as will hereafter be

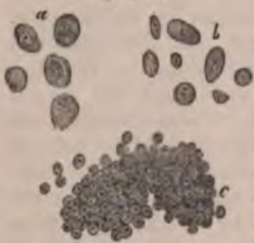
* A. Ganglionic nerve-cells detached.
B and C. Small portions of ganglion, in which the nerve-cells are seen imbedded among the gelatinous fibres. In C they are still covered by their capsule of nucleus-like corpuscles (*a*, *a*). Tubular fibres (*b*, *b*) are seen passing through the ganglion; *n* indicates the nucleus of the nerve-cells in all the figures.—(From Valentin.)

more particularly referred to. Sometimes, especially in young animals, a short process extends in form of a commissure from one cell to another. Nucleus. The *nucleus* (figs. 54′

Fig. 55′.*

and 55′, *n*), which takes no share in the caudate prolongations of the cell-wall, is evidently also of a vesicular structure; it has an eccentric position, and a very regular round or oval outline, usually much more strongly marked than that of the nerve-cell itself; its size, too, is less variable. Sometimes, though rarely, a cell contains two nuclei. Nucleolus. The *nucleolus* appears like a bright speck within the nucleus: it varies a good deal in size, being in many cases as large as a human blood particle, and sometimes considerably larger; it also would seem to be a vesicular body. There may be two or three nucleoli in one nucleus. The matter which fills the nerve-cell is usually finely granular, and slightly tinged throughout with a brownish-red colour; and cells are often seen, especially those of the large caudate kind, with one, or sometimes two, much deeper coloured brown patches, caused by groups of pigment-granules (fig. 55′, *c*, *d*); the colour is deeper in adult age than in infancy.

Fig. 56′.†



* Nerve-cells magnified 170 diameters. *a* and *b* from the cortical grey matter of the cerebellum; *c* and *d* from the spongy grey matter of the medulla oblongata.—(*a*, *c*, and *d* after Hannover.)

† *a*, Cells from the (cortical) grey matter of the brain. *b* and *c* are from the cortical substance of the cerebellum; *b* resemble detached

Other nerve-cells (fig. 56′, *a*) are found in the nervous substance, which are distinguished chiefly by the pellucid, colourless, and homogeneous aspect of the matter contained in them; such cells possess a nucleus like the rest, they are seldom large, and have usually a simple round or oval figure. They occur along with nerve-cells of the kind before described, and are perhaps merely an earlier condition of these. Lastly, small vesicular bodies of the size of human blood-corpuscles and upwards, containing one or more bright specks like nucleoli, abound in the grey matter in certain situations (fig. 56′, *b*, *c*). These bodies are exactly like the nuclei of the nerve-cells already described, and some of them may perhaps be really such nuclei escaped from cells crushed and broken down in the manipulation; but, looking to their numbers and dense array in certain regions (fig. 56′, *c*), their presence cannot well be generally referred to this cause, and it comes then to be a question, whether they are free nuclei destined to become inclosed in a cell of subsequent formation, or actually cells in which the cell-wall lies close to the nucleus, and cannot be distinguished from it. These nucleus-like corpuscles are very abundant in the superficial grey matter of the cerebellum.

Varieties.

Nucleus-like bodies.

In the grey matter of the cerebro-spinal centre, the nerve-cells are usually imbedded in a sort of matrix of granular substance, which is interposed between them in greater or less quantity, and is very generally traversed by nerve-fibres. In the ganglia properly so called, the cells are packed up among nerve-fibres, chiefly of the gelatinous kind; but each cell is also immediately surrounded by a coating or capsule formed of gelatinous fibres and a layer of granular corpuscles, not unlike the most common kind of granular cell-nuclei, united together by a pellucid substance (fig. 54′, *c*, *a*, *a*).

Such being the structural elements of the nervous substance, we have next to consider the arrangement of these cells and fibres in the ganglia and nerves which they contribute to form; the intimate structure of the encephalon and spinal cord being treated of in the part of this work which is devoted to special or descriptive anatomy.

cell-nuclei. *c* are smaller bodies, also like cell-nuclei, densely aggregated.—(After Hannover, magnified 340 diameters.)

OF THE GANGLIA.

Situation of ganglia.

The bodies so named are found in the following situations; viz.: 1. On the posterior root of each of the spinal nerves, on one, and probably the corresponding root of the fifth nerve of the encephalon, and on the seventh pair, glosso-pharyngeal and pneumogastric nerves, involving a greater or less amount of their fibres. 2. Belonging to the sympathetic nerve. (*a*)—In a series along each side of the vertebral column, connected by nervous cords, and constituting what was once considered as the trunk of the sympathetic. (*b*)—On branches of the sympathetic; occurring numerously in the abdomen, thorax, neck, and head; generally in the midst of plexuses, or at the point of union of two or more branches. Those which are found in several of the fossæ of the cranium and face are for the most part placed at the junction of fine branches of the sympathetic with branches, usually larger, of the cerebro-spinal nerves; but they are generally reckoned as belonging to the sympathetic system.

Size.

The ganglia differ widely from each other in figure and size: those which have been longest known to anatomists are most of them large and conspicuous objects; but, from the researches of Remak, it appears that there are numerous small, or what might be almost termed microscopic ganglia, connected with the nerves of the heart, lungs, and some other viscera.

Structure of ganglions.

Ganglions are invested externally with a thin but firm and closely adherent envelope, continuous with the neurilemma or sheath of the nerves, and composed of dense areolar tissue; this outward covering sends processes inwards through the interior mass, dividing it, as it were, into lobules, and supporting the numerous fine vessels which pervade it. A section carried through a ganglion, in the direction of the nervous cords connected with it, discloses to the naked eye merely a collection of reddish-grey matter traversed by the white fibres of the nerves. The nervous cords on entering the ganglion lay aside their membranous sheath, and spread out into smaller bundles, between which the grey ganglionic substance is interposed. The microscope shows that this grey substance consists of nerve-cells and gelatinous fibres. The nerve-cells, or ganglion globules, have mostly a round or oval figure, especially those situated towards the surface of the ganglion; those nearer the centre

are often angular or pointed, and many have caudate processes. Their cell-wall is said to be stronger than that of the cells found in the brain and spinal cord, and they are moreover enclosed in capsules formed of granular corpuscles and fibres (probably a modification of connective tissue), out of which they readily escape when the ganglion is torn up into fragments. The tubular nerve-fibres are, according to Valentin, disposed as follows: one part of them (fibræ transeuntes), keeping together in considerable bundles, run straight through the ganglion; the rest (fibræ circumflexæ seu circumnectentes) separate more from each other, and take a circuitous course among the nerve-cells, round which they make various turnings and windings before passing out of the ganglion. The bundles of straight fibres usually keep near the middle of the ganglion and are then surrounded by the globules, but frequently they run on one side. The winding fibres generally run nearer the surface; and when a series of ganglia are connected by a nervous cord, as in the trunk or main part of the sympathetic, it would seem that these winding fibres are destined to pass out in the branches given off from the ganglionic chain, whilst the straight fibres run on unchanged through two or three successive ganglia, until at length they in their turn assume the winding arrangement, approach the surface, and pass off into branches. The gelatinous fibres, leaving the ganglion, pass along the nervous cords with the tubular fibres, and their arrangement will be afterwards further noticed.

Connection of the nerve-fibres with the ganglia.

Remak and Hannover state that gelatinous fibres arise from the ganglion globules: Valentin, who denies the nervous nature of these fibres, maintains that they are connected only with the inclosing capsules of the ganglion globules, and not immediately with the globules themselves. As regards the connection of the tubular fibres with the ganglia, there is also a difference of opinion among those observers who have made this difficult point in anatomy a subject of special inquiry. Valentin held that these tubular fibres are all derived from the brain or spinal cord, and pass through the ganglia, coming, it is true, into close proximity and intimate functional relation with the ganglion globules, but none either originating or terminating in a ganglion; but it may now be considered as well established that a part of these fibres take their rise in the ganglia. This doctrine rests principally on the two following grounds;—1. That in

many cases the communicating nervous cords which conduct tubular fibres from the cerebro-spinal centre to the ganglia contain manifestly fewer of these fibres than are contained in the branches which pass off from the ganglia to be distributed peripherally. 2. The fact that the continuity of the fibres in question with the caudate processes of the ganglion globules may be traced by actual observation. Sometimes, as discovered by R. Wagner in the spinal ganglia of the skate, torpedo, and dog-fish, two fibres are connected with each ganglion-cell, at opposite sides or opposite poles, as it were—one directed centrally or towards the root of the nerve, and the other outwardly towards its branches; but in man and mammalia the cells are almost invariably unipolar, a cell being connected with but one fibre, and even where two fibres proceed from a cell they pass out in one direction. The nerve-fibre, as it leaves the cell, appears like a mere prolongation of it; the cell-wall is continuous with the tubular membrane of the fibre and the cell-contents with the axis-cylinder; further on the fibre increases in size, acquires its medullary sheath, and presents the usual characters of the tubular nerve-fibres.

CEREBRO-SPINAL NERVES.

Structure of nerves.

These are formed of the nerve-fibres already described, collected together and bound up in membranous sheaths. A larger or smaller number of fibres inclosed in a tubular sheath form a thin round cord, usually named a *funiculus*; if a nerve be very small it may consist of but one such cord, but in larger nerves several funiculi are united together into one or more larger bundles, which, being wrapped up in a common membranous covering, constitute

Funiculi.

Fasciculi.

Fig. 57′.*

the nerve (fig. 57′). Accordingly, in dissecting a nerve,

* Represents a nerve consisting of many smaller cords or funiculi wrapped up in a common areolar sheath.—A, the nerve. B, a single funiculus drawn out from the rest. (After Sir C. Bell.)

we first come to an outward covering, formed of areolar tissue, but often so strong and dense that it might well be called fibrous. From this common sheath we trace laminæ passing inwards between the larger and smaller bundles of funiculi, and finally between the funiculi themselves, connecting them together as well as conducting and supporting the fine blood-vessels which are distributed to the nerve. But, besides the interposed areolar tissue which connects these smallest cords, each funiculus has a distinct and independent tubular sheath of its own, as will be further noticed presently. Common sheath.

The common sheath and its subdivisions consist of areolar tissue, presenting the usual white and yellow constituent fibres of that texture, the latter being present in considerable proportion. The tubular sheaths of the funiculi, on the other hand, appear to be formed essentially of a fine transparent membrane, which may without difficulty be stripped off in form of a tube from the little bundle of nerve-fibres of which the funiculus consists. When examined with a high power of the microscope, this membrane presents the aspect of a thin transparent film, which in some parts appears to be quite simple and homogeneous, but is more generally marked with extremely fine reticulated fibres. Corpuscles resembling elongated cell-nuclei may also be seen upon it when acetic acid is applied.* The tissue investing a nerve and inclosing its proper fibres, as now described, is named the *neurilemma*, and the term is for the most part applied indiscriminately to the whole of the enveloping structure, though some anatomists use it to denote only the sheaths of the funiculi and smaller fasciculi, whilst they name the general external covering of the nerve its "cellular sheath" (*vagina cellulosa*). Nature of common sheath; of funicular sheaths; Use of the terms "neurilemma" and "cellular sheath."

The funiculi of a nerve are not all of one size, but all are sufficiently large to be readily seen with the naked eye, and easily dissected out from each other. In a nerve so dissected into its component funiculi, it is seen that these do not run along the nerve as parallel insulated cords, but join together obliquely at short distances as they proceed in their course, the cords resulting from such union dividing in Arrangement of funiculi.

* In several observations it has seemed to me that these corpuscles were attached to the inner surface of the membrane. Mr. Beck informs me that he has repeatedly found the membrane appearing as if composed of polygonal scales or tables, and hence he regards it as an epithelium. I have not succeeded in observing an epithelial structure in it.

their further progress to form junctions again with collateral cords; so that in fact the funiculi composing a single nervous trunk have an arrangement with respect to each other similar to that which we shall presently find to hold in a plexus formed by the branches of different nerves. It must be distinctly understood, however, that in these communications the proper nerve-fibres do not join together or coalesce. They pass off from one nervous cord to enter another, with whose fibres they become intermixed, and part of them thus intermixed may again pass off to a third funiculus, or go through a series of funiculi and undergo still further intermixture; but throughout all these successive associations the nerve-fibres remain, as far as known, individually distinct, like interlaced threads in a rope.

Fibres.

The fibres of the cerebro-spinal nerves are chiefly, in some cases perhaps exclusively, of the tubular kind, but in most instances there are also gelatinous fibres in greater or less number. Moreover, it has often appeared to me as if there were filaments of extreme tenuity, like the white filaments of areolar tissue, mixed up with the true nerve-fibres within the sheaths of the funiculi. Lying alongside each other, the fibres of a funiculus form a little skein or bundle, which runs in a waving or serpentine manner within its tubular sheath; and the alternate lights and shadows caused by the successive bendings being seen through the sheath, give rise to the appearance of alternate light and dark cross stripes on the funiculi, or even on larger cords consisting of several funiculi. On stretching the nerve, the fibres are straightened and the striped appearance is lost.

Blood-vessels of nerves.

Vessels.—The blood-vessels of a nerve supported by the neurilemma divide into very fine capillaries, said by Henle to measure in the empty state not more than $\frac{1}{5000}$th of an inch in diameter. These, which are numerous, run parallel with the funiculi, but are connected at intervals by short transverse branches, so as in fact to form a network with very long narrow meshes.

Branches of nerves.

Branching and conjunction of Nerves.—Nerves in their progress very commonly divide into branches, and the branches of different nerves not unfrequently join with each other. As regards the arrangement of the fibres in these cases, it is to be observed, that, in the branching of a nerve, portions of its fibres successively leave the trunk and form branches; and that, when different nerves or their

branches intercommunicate, fibres pass from one nerve to become associated with those of the other in their further progress; but in neither case (unless at their peripheral terminations) is there any such thing as a division or splitting of an elementary nerve-fibre into two, or an actual junction or coalescence of two such fibres together.

Communications of nerves.

A communication between two nerves is sometimes effected by one or two connecting branches. In such comparatively simple modes of connection, which are not unusual, both nerves commonly give and receive fibres; so that, after the junction, each contains a mixture of fibres derived from two originally distinct sources. More rarely the fibres pass only from one of the nerves to the other, and the contribution is not reciprocal. In the former case the communicating branch or branches will of course contain fibres of both nerves, in the latter of one only.

Plexus.

In other cases the branches of a nerve, or branches derived from two or from several different nerves, are connected in a more complicated manner, and form what is termed a plexus. In plexuses—of which the one named "brachial" or "axillary," formed by the great nerves of the arm, and the "lumbar" and "sacral," formed by those of the lower limb and pelvis, are appropriate examples—the nerves or their branches join and divide again and again, interchanging and intermixing their fibres so thoroughly, that, by the time a branch leaves the plexus, it may contain fibres from all the nerves entering the plexus. Still, as in the more simple communications already spoken of, the fibres remain individually distinct throughout.

Some farther circumstances remain to be noticed as to the course of the fibres in nerves and nervous plexuses.

Nervi nervorum.

Gerber * has described and figured nerve-fibres, which, after running a certain way in a nerve, apparently join in form of loops with neighbouring fibres of the same funiculus, and proceed no further. Such loops might of course be represented as formed by fibres which bend back and return to the nervous centre; and so Gerber considers them. He likens them to the loops said to be formed by the fibres at the extremities or peripheral terminations of nerves in various sentient parts, and regards them accordingly as the terminations of sentient fibres appropriated to the nerve itself—as the *nervi nervorum*, in short, on which depends the sensibility of the nerve to impressions, painful or otherwise, applied to it elsewhere than at its extremities. The whole matter is, however, involved in doubt: for, admitting the existence

* Handbuch der allgemeinen Anatomie, (1840,) § 267.

of the loops referred to, which yet requires confirmation, it is not impossible that they may be produced by fibres which run back only a certain way, and then, entering another funiculus, proceed onwards to the termination of the nerve. Again, it has been supposed, that, in some instances of nervous conjunctions, certain collections of fibres, after passing from one nerve to another, take a retrograde course in that second nerve, and, in place of being distributed peripherally with its branches, turn back to its root and rejoin the cerebro-spinal centre. An apparent example of such nervous arches without peripheral distribution is afforded by the optic nerves in which various anatomists admit the existence of arched fibres, that seem to pass across the commissure between these nerves from one optic tract to the other, and to return again to the brain. These, however, are perhaps to be compared with the commissural fibres of the brain itself, of which there is a great system connecting the symmetrical halves of that organ. But instances of a similar kind occurring in other nerves have been pointed out by Volkmann; * as in the connection between the second and third cervical nerves of the cat, also in that of the fourth cranial nerve with the first branch of the fifth in other quadrupeds, and in the communications of the cervical nerves with the spinal accessory and the descendens noni. But certain fibres of the optic nerves take a course deviating still more from that followed generally, for they appear to be continued across the commissure from the eyeball and optic nerve of one side to the opposite nerve and eye, without being connected with the brain at all, and thus forming arches with peripheral terminations, but no central connection. In looking, however, for an explanation of this arrangement, it must be borne in mind that the retina contains nerve-cells or vesicles, like those of the nervous centres, and perhaps the fibres referred to may be intended merely to bring the vesicular matter of the two sides into relation independently of the brain.

Fasciculi without peripheral termination.

Origins or roots of nerves.

Origins or Roots of the Nerves.—The cerebro-spinal nerves, as already said, are connected by one extremity to the brain or to the spinal cord, and this central extremity of a nerve is, in the language of anatomy, named its origin or root. In some cases the root is single, that is, the funiculi or fibres by which the nerve arises are all attached at one spot or along one line or tract; in other nerves, on the contrary, they form two or more separate collections, which arise apart from each other and are connected with different parts of the nervous centre, and such nerves are accordingly said to have two or more origins or roots. In the latter case, moreover, the different roots of a nerve may differ not only in their anatomical characters and connections, but also in function, as is well exemplified in the spinal nerves, each of which arises by two roots, an anterior and a posterior—the former containing the motory fibres of the nerve, the latter the sensory.

* Müller's Archiv. (1840) p. 510.

Distinction of apparent and real origins.

The fibres of a nerve, or at least a considerable share of them, may be traced to some depth in the substance of the brain or spinal cord, and hence the term "apparent or superficial origin" has been employed to denote the place where the root of a nerve is attached to the surface, in order to distinguish it from the "real or deep origin" which is beneath the surface and concealed from view.

Real or deep origin.

To trace the different nerves back to their real origin, and to determine the points where, and the modes in which their fibres are connected with the nervous centre, is a matter of great difficulty and uncertainty; and, accordingly, the statements of anatomists respecting the origin of particular nerves are in many cases conflicting and unsatisfactory. Confining ourselves here to what applies to the nerves generally, it may be stated, that their roots, or part of their roots, can usually be followed for some way beneath the surface, in form of white tracts or bands distinguishable from the surrounding substance; and very generally these tracts of origin may be traced towards deposits of grey nervous matter situated in the neighbourhood; such, for instance, as the central grey matter of the spinal cord, the grey nuclei of the pneumo-gastric and glosso-pharyngeal nerves, the corpora geniculata and other larger grey masses connected with the origin of the optic nerve. It would further seem probable that certain fibres of the nerve roots take their origin in these local deposits of grey matter, whilst others become continuous with the white fibres of the spinal cord or encephalon, which are themselves connected with the larger and more general collections of grey matter situated in the interior or on the surface of the cerebro-spinal centre.

Mode of connection with grey matter.

There is still much uncertainty as to the mode in which the nerve-fibres originating or terminating in the grey matter are related to its elements, and for the most part, indeed, individual fibres on being traced into the grey matter, become so hidden in the mass as to elude further scrutiny. Some anatomists have maintained that the fibres form loops or slings, which lie in the grey substance, but have apparently no organic connection with its elements. According to others, the nerve-fibres arise from the caudate nerve-cells, being prolongations of the filamentous processes issuing from these bodies, which, after proceeding a little distance from the cell, acquire the character of tubular fibres. It has been already stated that nerve-fibres are

connected in this way with the cells of the ganglia, and the testimony of many competent observers leaves no room to doubt that this is at least one mode in which the nerves are connected with the grey matter in the cerebro-spinal centre.

Arrangement of roots. Apparent origin.

The fibres of origin of a nerve, whether deeply implanted or not, on quitting the surface of the brain or spinal cord to form the apparent origin or free part of the root, are in most cases collected into funiculi, which are each invested with a sheath of neurilemma. This investment is generally regarded as a prolongation of the pia mater, and in fact its continuity with that membrane may be seen very plainly at the roots of several of the nerves, especially those of the cervical and dorsal nerves within the vertebral canal, for in that situation the neurilemma, like the pia mater itself, is much stronger than in the cranium. The funiculi, approaching each other if originally scattered, advance towards the foramen of the skull or spine which gives issue to the nerve, and pass through the dura mater, either in one bundle and by a single aperture, or in two or more fasciculi, for which there are two or more openings in the membrane. The nerve roots in their course run beneath the arachnoid membrane, and do not perforate it on issuing from the cranio-vertebral cavity; for the loose or visceral layer of the arachnoid is prolonged on the nerve and loosely surrounds it as far as the aperture of egress in the dura mater, where, quitting the nerve, it is reflected upon the inner surface of the latter membrane, and becomes continuous with the parietal or adherent layer of the arachnoid. The nerve, on escaping from the skull or spine, acquires its external, stout, fibro-areolar sheath, which connects all its funiculi into a firm cord, and then, too, the nerve appears much thicker than before its exit. The dura mater accompanies the nerves through the bony foramina, and becomes continuous with their external sheath and (at the cranial foramina) with the pericranium; but the sheath does not long retain the densely fibrous character of the membrane with which it is thus connected at its commencement.

Exit from cranium and spine.

Peculiarities of intra-cranial part of certain nerves.

The arrangement of the membranes on the roots of certain of the cranial nerves requires to be specially noticed.

The numerous fasciculi of the olfactory nerve pass through their foramina almost immediately after springing from the olfactory bulb, and then also receive their neurilemma. The bulb itself, and intracranial part of the nerve, which are to be regarded as being really a

prolongation or lobe of the brain, are invested externally by the pia mater, but are not fasciculated. The arachnoid membrane passes over the furrow of the brain in which this part of the nerve lies, without affording it a special investment.

The optic nerve becomes subdivided internally into longitudinal fasciculi by neurilemma a little way in front of the commissure: on passing through the optic foramen it receives a sheath of dura mater, which accompanies it as far as the eyeball. The acoustic nerve becomes fasciculated, receives its neurilemma, and acquires a firm structure on entering the meatus auditorius internus in the temporal bone, towards the bottom of which it presents one or more small ganglionic swellings containing the characteristic cells. Up to this point it is destitute of neurilemma, and of soft consistence, whence the name "portio mollis" applied to it.

The larger root of the fifth pair acquires its neurilemma and its fasciculated character sooner at its circumference than in the centre, so that, in the round bunch of cords of which it consists, those placed more outwardly are longer than those within, and, when all are pulled away, the non-fascicular part of the nerve remains in form of a small conical eminence of comparatively soft nervous substance.

Most of the nerves have ganglia connected with their roots. Thus, the spinal nerves have each a ganglion on the posterior of the two roots by which they arise; and in like manner several of the cranial, viz., the fifth, seventh, glosso-pharyngeal, and pneumo-gastric, are furnished at their roots, or at least within a short distance of their origin, with ganglia which involve a greater or less number of their fibres, as described elsewhere in the special anatomy of those nerves.

Termination or peripheral extremity of Nerves. — The results of modern microscopic discovery seemed for a time to lead to the conclusion that the fibres of nerves do not, strictly speaking, end in the tissues in which they are distributed, but merely dip into those tissues, as it were, and, after forming slings or loops of greater or less width, return sooner or later to the nervous trunks. The further progress of inquiry has, however, shown—First, that the disposition of the elementary fibres in terminal loops or in terminal plexuses, through which they return again towards the parent trunks, is by no means general; that they more commonly end by simply truncated or slightly swollen extremities, as in the instance, to be presently described, of those entering the Pacinian bodies, or become gradually lost to the sight in the surrounding tissue, usually after considerable reduction in size, and after laying aside their dark outline, probably from privation of their white substance. That, even where apparently terminal loops are observed, it

Termination of nerves, in general:

is difficult to say whether these may not, in some cases, be caused by serpentine windings of the fibres previous to their actual termination, which may itself be hidden from view. Secondly, that elementary nerve-fibres, although, as far as is known, they keep entire and distinct in their course along the nerves, do in various instances actually divide into branches and in some cases unite or inosculate with each other, in approaching their termination. Thirdly, that in certain cases the fibres of the nerves of special sense, come into near relation at their peripheral extremities with cells resembling the nerve-cells of the brain and ganglia*.

in the skin; For an account of the termination of the nerves in different tissues and organs the reader is referred to the several heads under which these are treated of; but it will be convenient here specially to consider their mode of distribution in the skin and in analogous parts of mucous membrane endowed with a considerable degree of tactile sensibility.

in the skin of the frog; In the skin of the frog the nerves break up into branches which become smaller by repeated division, and are at length reduced to fine bundles of only two or three fibres each. The branches frequently join and separate, and the larger ones are observed very generally to run alongside the blood-vessels: the finest ramifications form at last a close network, in which they mutually give and receive fibres, and many of the individual fibres divide dichotomously again and again, and thus extend themselves over a larger space. From this plexus fibres pass through the superjacent layers of membrane towards the surface of the skin, and there form a superficial plexus among the cutaneous glands. In the eyelid of the frog, also, in which the plexiform arrangement of the fine nervous branches is readily seen, Henle observed nerve-fibres which ran singly a long way, and then disappeared, there being no evidence that they were continuous with others in form of loops; some seemed to end abruptly, and this appearance, which Henle was disposed to consider fallacious, has since been described again by Hannover, who moreover saw other primitive fibres dividing into finer filaments, which were arranged into a plexus, and ultimately eluded the sight.

of the tadpole, &c.; To these examples must be added the very remarkable observations of Schwann on the terminations of the nerves in the web or fin of the tadpole's tail. In that instance, as well as in the mesentery of amphibia, it appeared to Schwann, that the ordinary primitive nerve-fibres, after separating from the fasciculi, divided into other fibres of much smaller size, and that the finer fibres resulting from this division, which were

* It may not be out of place here to remark, that M. Quatrefages describes the cutaneous nerves of the singularly-organised fish named the Amphioxus or Branchiostoma, as finally dividing into excessively delicate homogeneous fibres, each of which terminates singly in a little oval body below the fine integument. In the figure which accompanies his description, the small terminal bodies referred to appear not unlike oval cells.

destitute of white substance and wanted the dark outline, here and there presented little enlargements or nodules, from whence, again, delicate fibres spread out in various directions, and connected themselves in form of a network.* Subsequent observations made by myself, on the nerves of the tail of the tadpole, are confirmatory of those of Schwann. The fine fibres, which are derived from the division of the ordinary ones, want the bold, dark outline which usually marks the tubular fibres; they also present here and there along their course elongated corpuscles like cell-nuclei, and, from their similarity in aspect to the gelatinous fibres, it might be supposed that they are really prolonged from gelatinous fibres mixed up with the tubular kind in the nervous branches; there can be no doubt, however, as to their source, for fine tubular fibres may be traced, which change in character as they proceed, lose their dark outline, and pass continuously into these pale nucleiferous fibres; moreover, many of the decidedly tubular fibres in this situation are marked with nucleus-like corpuscles. The tubular fibres might thus be represented as laying aside their white substance and dark outline before dividing or terminating, like those ending in the Pacinian bodies, to be presently described; but in the present case (of the growing tail of the tadpole) the pale fibres are in reality to be considered as an earlier condition of tubular fibres in progress of development. Schwann, who adopts this view, states that the pale fibres are the forerunners of tubular fibres, and he conceives that they are converted into the latter by acquiring the white substance (medullary sheath), and with this the dark outline. Still, whether perfect or not, these fine fibres must be capable of receiving and conducting sensorial impressions applied to the decidedly sentient membrane in which they are distributed. Kölliker has observed loops formed by the tubular fibres in the tadpole's tail, also divisions of the tubular fibres, of which I may add that I have also met with one instance.

In skin of man and quadrupeds. The density and opacity of the cutaneous tissue in man and quadrupeds render the investigation of the ultimate distribution of the cutaneous nerves extremely difficult. As far as can be ascertained they end in a plexus in which divisions, conjunctions, and free terminations of the fibres have been observed. Nerve-fibres pass into the cutaneous papillæ, but their final disposition in these eminences is not certainly known. Kölliker maintains that they form loops, although he does not hold this to be the only mode in which they end in the papillæ. On the other hand, Todd and Bowman, although they saw bunches of loop-like fibres in the papillæ of the tongue, which in many respects resemble the cutaneous papillæ, nevertheless failed to detect any such loops in the papillæ of the skin; they were able to trace solitary nerve tubules ascending a certain way into the papillæ, and then becoming lost to sight, either by simply ending, or else by losing their white substance, by which only they are distinguishable from the fibres of other tissues in this situation. This account agrees essentially with that since given by Ecker. The relation of

* These little radiating knots, which are supposed by Schwann to be the remnants of cells from which the fibres are developed, are not to be confounded with the ramified colourless cells (resembling in figure branched pigment-cells) which abound in the tissue in which the nerves are distributed. I have never been able to perceive any connection between the nerve-fibres and these last-mentioned cells.

the nerves to the so-called *corpuscula tactûs* of the papillæ will be considered in treating of the skin.

Pacinian bodies: In dissecting the nerves of the hand and foot, certain small oval bodies, like little seeds, are found attached to their branches as they pass through the subcutaneous fat on their way to the skin; and it has been ascertained that each of these bodies receives a nervous fibre which terminates within it. The objects referred to were more than a century ago described and figured by Vater,† as attached to the digital nerves, but he did not examine into their structure, and his observation seems not to have attracted much notice. Within the last few years, their existence has been again pointed out by Cruveilhier and other French anatomists, as well as by Professor Pacini of Pisa, who appears to be the first writer that has given an account of the internal structure of these curious bodies and clearly demonstrated their essential connection with the nervous fibres. The researches of Pacini have been followed up by Henle and Kölliker,‡ who named the corpuscles after the Italian savant; and to their memoir, as well as to the article "Pacinian Bodies," by Mr. Bowman, in the "Cyclopædia of Anatomy," the reader is referred for details that cannot be conveniently introduced here.

Fig. 58′.*

where found; The little bodies in question (fig. 58′) are, as already said, attached in great numbers to the branches of the nerves of the hand and foot, and here and there one or two are found on other cutaneous nerves. They have been discovered also within the abdomen on the nerves of the solar plexus, and they are nowhere more distinctly seen or more conveniently obtained for examination, than in the mesentery and omentum of the cat, between the layers of which they exist abundantly. They have been found on the pudic nerves on the glans penis and bulb of the urethra, on the intercostal nerves, sacral plexus, cutaneous nerves of the upper arm and neck, and on the infraorbital nerve. They are found in the fœtus, and in individuals of all ages.

shape and size; The figure of these corpuscles is oval, somewhat like that of a grain of wheat,—regularly oval in the cat, but mostly curved or reniform in man, and sometimes a good deal distorted. Their mean size in the adult is from $\frac{1}{15}$th to $\frac{1}{10}$th of an inch long, and from $\frac{1}{30}$th to $\frac{1}{20}$th of an inch broad. They have a whitish, opaline aspect: in the cat's mesentery they are usually more transparent, and

pedicle; then a white line may be distinguished in the centre. A slender stalk

* A nerve of the middle finger, with Pacinian bodies attached. Natural size. (After Henle and Kölliker.)

† Abr. Vater, Diss. de Consensu Partium Corp. hum.; Vitemb. 1741, (recus. in Halleri Disp. Anat. Select. tom. ii.) Ejusd. Museum Anatomicum; Helmst. 1750.

‡ Ueber die Pacinischen Körperchen; Zurich, 1844.

or peduncle attaches the corpuscle to the branch of nerve with which it is connected. The peduncle consists of a single tubular nerve-fibre ensheathed in filamentous areolar tissue, with one or more fine blood-vessels; and it joins the corpuscle at or near one end, and conducts

Fig. 59′.*

the nerve-fibre into it. The little body itself, examined under the microscope, is found to have a beautiful lamellar structure (fig. 59′, A). Internal structure

* A. Magnified view of a Pacinian body from the mesentery of a cat, showing the lamellar structure, the capsules with their nuclei, the inner and closer series of capsules appearing darker in the figure, the nerve-fibre passing along the peduncle, and penetrating the capsules to reach the central cavity, where it loses its strong, dark outline, and terminates by an irregular knob at the distal and here dilated end of the cavity. Areolar tissue (neurilemma) and blood-vessels are represented in the peduncle, and tortuous capillaries are seen running up among the capsules. B and C represent the termination of the nerve with the distal end of the central cavity and adjoining capsules, to illustrate varieties of arrangement. In B the fibre, as well as the cavity and capsules, is bifurcated.

It consists, in fact, of numerous concentric membranous capsules incasing each other like the coats of an onion, with a small quantity of transparent and probably albuminous matter lodged between them, the innermost containing a cylindrical cavity filled with the same kind of matter, into which the nerve-fibre passes. This transparent substance was at first supposed to be fluid, but has since been found to be of a solid or gelatinous consistence. The number of capsules is various; from forty to sixty may be counted in large corpuscles. The series immediately following the central or median cavity, and comprehending about half of the entire number, are closer together than the more exterior ones, seeming to form a system by themselves, which gives rise to a white streak often distinguishable by the eye along the middle of the corpuscles when seen on a dark ground. Outside of all, the corpuscle has a coating of ordinary areolar tissue. The capsules, at least the more superficial ones, consist each of an internal layer of longitudinal and an external of circular fibres, which resemble the white fibres of areolar and fibrous tissue, with cell-nuclei attached here and there on the inner layer, and a few branched fibres of the yellow or elastic kind running on the outer. The nerve-fibre, conducted along the centre of the stalk, enters the corpuscle, and passes straight into the central cavity, at the further end of which it terminates.

The fibrous neurilemma surrounding the nerve-fibre in the peduncle accompanies it also in its passage through the series of capsules, gradually decreasing in thickness as it proceeds, and ceasing altogether when the nerve has reached the central cavity. According to Pacini, with whom Reichert agrees in this particular, the neurilemma forms a series of concentric cylindrical layers, which successively become continuous with, or rather expand into the capsules, the innermost, of course, advancing farthest. Others suppose that the capsules are all successively perforated by a conical channel which gives passage to the nerve with its neurilemma, but at the same time has its own proper wall, round which, on the outside, the capsules are attached. Whichever view may be correct, the capsules are, as it were, strung together where the nerve passes through them, and each intercapsular space, with its contained matter, is shut off from the neighbouring ones. The nerve-fibre, the disposition of which must now be noticed, is single as it runs along the peduncle, unless when the latter supports two corpuscles; it retains its dark double contour until it reaches the central cavity, where, diminished in size, and freed from its neurilemma, it becomes somewhat flattened, and presents the appearance either of a pale, finely granular, and very faintly-outlined band or stripe, little narrower than the previous part of the fibre, or of a darker and more sharply defined narrow line; differing thus in appearance according as its flat side or its edge is turned towards the eye. The pale aspect which the fibre presents in the centre of the corpuscle has with some probability been ascribed to its losing the white substance or medullary sheath on entering the cavity; Henle and Kölliker, however, think that it is more likely the result merely of a diminution in size together with a certain degree of flattening. It sometimes happens that the fibre regains its original magnitude and double contour for a short space, and changes again before it terminates; this is especially liable to occur while it passes through a sharp flexure in a crooked central cavity. The fibre ends by a sort of knob at the further extremity of the median cavity, which is often itself somewhat dilated. In many

Termination of nerve-fibre.

cases, the fibre, before terminating, divides into two branches, as represented in figure B: a division into three has been observed, but this is very rare. In case of division of the fibre, the cavity is generally, but not invariably, divided in a corresponding measure, and the inner set of capsules present a figure in keeping with it. It is worthy of remark, that the nerve-fibre in its course along the cavity runs almost exactly in the axis, and it maintains this position even when passing through the abrupt flexures of an irregularly-shaped cavity. It sometimes happens that a fibre passes quite through one corpuscle and terminates in a second, resuming its original size and dark outline while passing from the one to the other. Pappenheim states that he has seen a nerve-fibre going through two Pacinian bodies without terminating in either, but returning again to the parent nerve in form of a loop. Other varieties occur, for an account of which the reader is referred to the several authorities already mentioned. A little artery enters the Pacinian bodies along with the nerve, and soon divides into capillary branches, which pierce the parietes of the passage and run up between the capsules. Mr. Bowman finds that they then form loops, and return by a similar route into a vein corresponding to the artery: he states also that a single capillary usually accompanies the nerve as far as the central capsule, and passes some way on its wall, sometimes in a spiral direction.

Varieties.

Blood-vessels.

Nothing positive is known concerning the purpose in the animal economy which these curious appendages of the nerves are destined to fulfil. After passing in review various conjectures which naturally suggest themselves, Pacini, and, after him, Henle and Kölliker, looking to a certain correspondence in structure between these little bodies and the electric organs of the torpedo and other similarly-endowed fishes, are disposed to think that the most promising hypothesis which can in the meantime be adopted is that they are analogous in function with these electric organs. It must be confessed, however, that any experiments that have been instituted for the purpose have as yet altogether failed to elicit proof that the Pacinian bodies develope electricity. Cruveilhier and others suppose that they are morbid or accidental productions, probably resulting from pressure applied to the nerves; but their constant presence (at least in certain regions in the body) in perfectly healthy individuals, at all periods of life, and even in the fœtus, and, above all, their regular and elaborate internal structure, forbid us to regard them as the result of accident or disease.

Supposed function.

As connected with the present subject, I cannot avoid adverting to the remarkable fact discovered by Savi, respecting the terminal fibres of the nerves distributed on the horizontal membranous partitions or diaphragms in the electric apparatus of the torpedo, namely, that these fibres or elementary tubules actually bifurcate or divide dichotomously into branches possessing the same tubular character, which inosculate together so as to form a network. Wagner, who has since examined this structure, recognises the division of the tubular fibres, but denies the net-like conjunctions; he states that the nervous tubules divide at first not dichotomously, but into several branches which divaricate from the same point, and then, after repeatedly bifurcating, become greatly reduced in size, lose their dark outline and double contour, and at length can be no longer distinguished from the tissue in which they lie. Robin * states that he has observed the division as well as the

Termination of nerves in electric organs.

* Annales des Sc. Nat., Mai, 1847.

reticular inosculations of the terminal nerve tubules in an organ which has been lately discovered in the tail of various common species of rays, and which, in respect of intimate structure at least, offers considerable resemblance to the electric apparatus of the torpedo. I have myself seen the division of the tubular nerve-fibres (though I cannot say how they terminate) in the organ referred to, which, it may be well to add, was discovered by Dr. Stark, of Edinburgh, in 1844, and regarded by him as an electric apparatus.*

Peculiarities of different nerves.

Differences of cerebro-spinal Nerves.—It remains to notice the differences which have been observed among the cerebro-spinal nerves in regard to the size of their fibres, and the proportionate amount of the different kinds of fibres which they respectively contain.

As already stated, both tubular and gelatinous fibres exist in cerebro-spinal nerves, and those of the tubular kind differ greatly from each other in size; but some anatomists consider that two different average sizes prevail among the tubular fibres, scarcely, if at all, connected by intermediate gradations; they accordingly distinguish two varieties of them, characterised by their size; and Volkmann and Bidder, as will be more fully explained in treating of the sympathetic nerve, are further of opinion that the small kind are a system of nervous fibres derived from the ganglia. Be this as it may, the authors just named have bestowed much pains in endeavouring to arrive at an approximate estimate of the relative amount of the large and the small fibres in different nerves, and the following are the more important results of their researches:—

Amount of large and small fibres in different nerves.

1. The nerves of voluntary muscles have very few small fibres, usually in not larger proportion than about one to ten.
2. In the nerves of involuntary muscles, whether derived immediately from the cerebro-spinal system or from the sympathetic, the small fibres eminently preponderate, being about a hundred to one.
3. The nerves going to the integuments have always many small fibres, at least as many small as large.
4. Nerves of sentient parts of mucous membranes have from five to twenty times more small fibres than large: in mucous membranes possessing little sensibility the nerves are made up chiefly of small fibres. The nerves distributed in the pulp of the teeth consist principally of large fibres.

It is plain, however, that Volkmann and Bidder must have reckoned in with their small fibres more or fewer of the gelatinous sort, so that the proportion assigned to the small fibres in their estimate must be taken as including gelatinous as well as tubular fibres; and this agrees with the observation previously made by Remak, that many more gelatinous fibres are contained in the cutaneous than in the muscular nerves. The roots of the spinal nerves contain fine fibres, but according to Remak only in very small proportion: Volkmann and Bidder state that in man the anterior roots contain proportionally more large fibres than the posterior. In almost all nerves the fibres diminish in size as they approach their termination.

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* Magazine of Natural History, vol. xv. p. 121.

Fibres of optic, auditory, and olfactory nerves.

The fibres of the optic nerve for the most part resemble the white fibres of the brain, and readily become varicose. The same is true of the acoustic nerve, from its origin to its entrance into the internal auditory foramen, where it becomes fasciculated; also of the intracranial part of the olfactory, which, however, contains in addition grey matter and nerve-cells. The branches of the olfactory in the nose are almost wholly made up of fibres bearing nuclei, and having all the outward characters of the gelatinous fibres, like which, also, they cohere or cling fast together in the bundles which they form. Some branches seem to consist entirely of such fibres; others contain a few tubular fibres intermixed, which, however, may perhaps be derived from the nasal branches of the fifth pair. This peculiarity of the branches of the olfactory nerve, distinguishing it so much from other cerebral nerves, was, as far as I know, first distinctly pointed out by Todd and Bowman, although it seems not altogether to have escaped the notice of preceding anatomists, of Valentin, for instance, who compares the branches of the olfactory to the nervi molles of the sympathetic.

OF THE SYMPATHETIC OR GANGLIONIC NERVE.

General arrangement.

This name is commonly applied to a nerve or system of nerves present on both sides of the body, and consisting of the following parts, viz.:—1. A series of ganglia, placed along the spinal column by the side of the vertebræ, connected with each other by an intermediate nerve-cord, and extending upwards to the base of the skull and downwards as far as the coccyx. This principal chain of ganglia, with the cord connecting them, forms what is often named the trunk of the sympathetic. 2. Communicating branches, which connect these ganglia or the intermediate cord with all the spinal and several of the cranial nerves. 3. Primary branches passing off from the ganglionic chain or trunk of the nerve, and either bestowing themselves at once, and generally in form of plexuses, on the neighbouring blood-vessels, glands, and other organs, or, as is the case with the greater number, proceeding in the first instance to other ganglia of greater or less size (sometimes named prævertebral), situated in the thorax, abdomen, and pelvis, and usually collected into groups or coalescing into larger ganglionic masses near the roots of the great arteries of the viscera. 4. Numerous plexuses of nerves, sent off from these visceral or prævertebral ganglia to the viscera, usually creeping along the branches of arteries, and containing in various parts little ganglia disseminated among them. Some of these plexuses also receive contributions from spinal or cerebral nerves, by means of branches which immediately proceed to them without previously joining the main series of ganglia.

Structure of the sympathetic nerve.

Structure of the sympathetic nerve.—The nervous cords of the sympathetic consist of tubular fibres, and of gelatinous fibres mixed with a greater or less amount of filamentous areolar tissue, and inclosed in a common external fibro-areolar sheath. The tubular fibres differ greatly from each other in thickness. A few are of large size, ranging from $\frac{1}{2000}$th to $\frac{1}{1500}$th of an inch; but the greater number are of much smaller dimensions, measuring from about $\frac{1}{8300}$th to $\frac{1}{4500}$th of an inch in diameter, and, though having a well-defined sharp outline, for the most part fail to present the distinct double contour seen in the larger and more typical examples of the tubular fibre. It is stated by Remak that these fibres present nuclei having the characters of those which are seen on the grey fibres, but that they exist in smaller numbers. This statement is confirmed by Henle and Leydig. The gelatinous fibres present the characters already described as pertaining to them.

Difference of grey and white cords.

The more grey-looking branches or bundles of the sympathetic consist of a large number of the gelatinous fibres mixed with a few of the tubular kind; the whiter cords, on the other hand, contain a proportionally large amount of tubular fibres, and fewer of the gelatinous; and in some parts of the nerve grey fasciculi and white fasciculi, respectively constituted as above described, run alongside of each other in the same cords for a considerable space without mixing. This arrangement may be seen in some of the branches of communication with the spinal nerves, in the trunk or cord which connects together the principal chain of ganglia, and in the primary branches proceeding from thence to the viscera. In the last-mentioned case the different fasciculi get more mixed as they advance, but generally it is only after the white fasciculi have passed through one or more ganglia that they become thoroughly blended with the grey; and then, too, the nervous cords receive a large accession of gelatinous fibres (apparently derived from the ganglia), which are mixed up with the rest, and take off more and more from their whiteness.

Nature of the gelatinous fibres.

Regarding the nature of the gelatinous fibres, there is, as has already been remarked, a wide difference of opinion, for several anatomists of reputation deny that they are nervous fibres at all: it becomes necessary, therefore, before proceeding further, to consider briefly this question.

Those who deny the nervous nature of these fibres, rely chiefly on the difference in aspect and anatomical characters between them and undoubted nervous fibres, and account for their presence in the nerves

by referring them to the class of enveloping structures; maintaining, in short, that they are nothing but fibres of areolar tissue imperfectly developed or otherwise modified, and that they serve merely as a sort of neurilemma for the tubular or true nervous fibres. To this it may be replied, in the first place, that the large proportionate amount of gelatinous fibres in many branches of the sympathetic nerve, and their varying arrangement in respect of the tubular fibres associated with them, do not accord with the idea of an enveloping tissue. Next, as regards discrepancy in structure and outward aspect, we may call to mind the instance of the striped and plain muscular fibres, as satisfactorily proving that textures differing widely in anatomical characters may yet fundamentally agree in function and vital endowments. Moreover, it is not correct to say that the gelatinous fibres have the characters of areolar tissue either perfectly or imperfectly formed; it would be much nearer the truth to compare their appearance, as some have done, to that of the tubular nervous fibres in an early stage of development, although in saying this it is not meant that they are actually unfinished nervous fibres. If there be transitions, as is said, between the gelatinous fibres and the filaments of areolar tissue, transitions, too, it may be replied, are not wanting between them and the tubular nerve-fibres. Thus, Purkinje, and subsequently Remak and others, have described small-sized pale fibres bearing nuclei, and thus in so far agreeing with gelatinous fibres, but, nevertheless, filled with oleaginous fluid contents like the tubular; and so slight, indeed, would seem to be the gradations with which the two kinds of fibres pass into each other, that Volkmann and Bidder, both excellent observers, have been taxed with unwittingly reckoning gelatinous fibres among those which they consider as the true nervous fibres, while professing to distinguish between them. Again, an undoubted nervous tubule may in some part of its course assume characters approaching closely to those of the fibres in dispute. Thus, it is no uncommon thing for a tubular fibre of the most typical form, in approaching its termination, to decrease in size, lose its double contour, and present the faint outline and finely granular aspect of a gelatinous fibre: we have seen that this change always occurs when a fibre enters a Pacinian body; and in the tadpole's tail, as already described, nervous tubules are continued into fibres which are marked with nuclei, and wholly agree in appearance with the gelatinous fibres; these are probably immature, it is true, but yet they are distributed to a sentient part, and are capable of conducting sensorial impressions. It would seem as if the difference in more obvious characters between the different parts of the fibres in these cases, and perhaps also that between nerve-fibres in general, depended mainly on their respective size, and on the different proportion of their white substance, as well as on the presence or absence of nucleiform corpuscles. Were further proof wanting that a pale faintly granular aspect, want of dark outline, cohesion with its neighbours, and abundant nuclei along its course, ought not to be considered as depriving a fibre of its nervous character, we need only refer to the structure of the nasal part of the olfactory nerve already pointed out.

But it is further objected, that, whilst tubular fibres have been seen to arise from ganglionic cells, those of the gelatinous sort are unconnected with these bodies, and appear to proceed from their inclosing capsules, a difference both distinguishing them from nervous fibres, and indicative of their enveloping or neurilemmatic character. Without,

however, admitting or denying the force of this objection, were it founded in fact, it must be remembered that it rests principally on negative evidence directly opposed by the positive observations of Remak and Hannover; and the strenuous denial by Valentin and other highly respectable authorities, of the connection even of the tubular fibres with ganglionic cells,—a connection which has been so decidedly established by subsequent observations,—ought to render us distrustful of an objection resting on negative evidence in a case so nearly analogous.

In the last place, it is asserted that the gelatinous fibres do not continue in the nerves as far as their extremities, and that they are accordingly wanting in the branches of nerves distributed in the coats of the intestines, and in various other parts supplied by the sympathetic. But this statement is inconsistent with the observations both of Remak * and of Beck; † and the latter observer maintains even that very fine bundles of the sympathetic sometimes consist solely of gelatinous fibres.

Kölliker considers that only a portion of the so-called grey nerve-fibres belong in reality to the nervous system, the rest forming part of the connective tissues. Those which are truly tubes he thinks are always nerves; but with regard to the finer fibres, states that their continuity or non-continuity with dark-bordered fibres can alone enable us to decide upon their real nature.

Relation of sympathetic to cerebro-spinal nerves.

We have next shortly to consider the relation between the sympathetic and the cerebro-spinal system of nerves. On this important question two very different opinions have long existed, in one modification or another, amongst anatomists. 1. According to one, which is of old date, but which has lately been revived and ably advocated by Valentin, the sympathetic nerve is a mere dependency, offset, or embranchment of the cerebro-spinal system of nerves, containing no fibres but such as centre in the brain and cord, although it is held that these fibres are modified in their motor and sensory properties in passing through the ganglia in their way to and from the viscera and involuntary organs. 2. According to the other view, the sympathetic nerve (commonly so called) not only contains fibres derived from the brain and cord, but also proper or intrinsic fibres which take their rise in the ganglia; and in its communications with the spinal and cranial nerves, not only receives from these nerves cerebro-spinal fibres, but imparts to them a share of its own proper ganglionic fibres, to be incorporated in their branches and distributed peripherally with them. Therefore, according to this latter view, the sympathetic nerve, commonly so called, though

* De Syst. Nerv. Struct. p. 25. † Phil. Trans., 1846, p. 216.

not a mere offset of the cerebro-spinal nerves, yet, receiving as it does a share of their fibres, is not wholly independent, and for a like reason the cerebro-spinal nerves (as commonly understood) cannot be considered as constituted independently of the sympathetic; in short, both the cerebro-spinal and the sympathetic are mixed nerves, that is, the branches of either system consist of two sets of fibres of different and independent origin, one connected centrally with the brain and cord, the other with the ganglia. Hence, if we look to the central connection of their fibres as the essential ground of distinction among nerves, the cerebro-spinal system of nerves might, strictly speaking, be considered as consisting of and comprehending all the fibres having their centre in the cerebro-spinal axis, whether these fibres run in the nerves usually denominated cerebral and spinal, or are distributed to the viscera in the branches of the nerve usually named the sympathetic; and, on the same ground, the sympathetic or ganglionic system, strictly and properly so called, would consist of and comprehend all the fibres connected centrally with the ganglia, wherever such fibres exist and into whatever combinations they enter, whether proceeding to the viscera or distributed peripherally with the nerves of the body generally; the ganglia on the roots of the spinal and cerebral nerves, with the nerve-fibres emanating from them, being reckoned into this system, as well as those usually denominated sympathetic. While ready, however, to acquiesce in the justice of the above distinction, we do not mean to employ the terms already in use in a sense different from that which is currently received.

In endeavouring to decide between the two views above stated, it may be first observed that the existence in the sympathetic nerve of fibres connected centrally with the cerebro-spinal axis, is proved not only by tracing bundles of fibres from the roots of the spinal nerves along the communicating branches and into the sympathetic, but by the pain or uneasy sensations which arise from disease or disturbance of organs, such as the intestines, supplied exclusively by what are considered branches of the sympathetic, by experiments on living or recently-killed animals, in which artificial irritation of the roots of the spinal nerves, or of various parts of the cerebro-spinal centre, caused movements of the viscera, and by experiments on the sympathetic nerve in the neck, by which it is shown that the dilatation of the pupil and the tonicity of the cutaneous vessels of the head are dependent on fibres which pass along the sympathetic nerve but are centrally connected with the upper part of the spinal cord.

These facts, it is evident, accord with both of the above-mentioned opinions respecting the constitution of the sympathetic; but it may be

further shown that this nerve contains fibres which arise from the ganglia and take a peripheral course, so that the second of the two opinions approaches nearer to the truth. In support of this assertion we may adduce the actual observation of nerve-fibres proceeding from the nerve-cells of the ganglia in a peripheral direction only; and there are also other grounds for believing that more fibres pass out of the sympathetic ganglia than can possibly be derived from the brain and cord. This seems to follow from a comparison of the aggregate size of the branches issuing from these ganglia with that of all the branches which can be supposed to enter them. To explain this, however, we must first consider the mode of communication between the sympathetic and spinal nerves.

Communications between sympathetic and cerebro-spinal nerves.

The branches of communication which pass between the ganglia or gangliated cord of the sympathetic and the spinal nerves, are connected with the anterior and greater branch of each of the latter nerves, a little in advance of the spinal ganglion; and at the point of connection the communicating branch in most cases divides into two portions, one, central, running towards the roots of the spinal nerve and the spinal cord, the other, peripheral, taking an outward course along with the anterior branch of the spinal nerve, with which it becomes incorporated and distributed. It can scarcely be doubted that the central portion, whilst it may contain fibres sent by the sympathetic to the spinal nerves or to the spinal cord, must necessarily contain all those which proceed from the cord to the sympathetic, and that, on the other hand, the peripheral division must consist of fibres immediately proceeding from the sympathetic and distributed peripherally with the spinal nerve. It is further observed, that in some of the junctions with the spinal nerves, the central and peripheral divisions of the communicating branch are about equal in size, and that in others the central part is greater than the peripheral, whilst in others, again, the peripheral prevails over the central. Now, in an animal such as the frog, in which the spinal nerves are of small size and few in number, it is possible, with the aid of the microscope, to compare by measurement the central and peripheral divisions of the communicating branch in all the communications between the sympathetic and the spinal nerves, or even to count the fibres when the branches are very fine; and by such a comparison Volkmann and Bidder have shown, that, after making all reasonable deductions and allowances, the whole amount of the fibres, or at least the aggregate bulk of the fasciculi, which obviously pass from the sympathetic and run outwards with the spinal nerves, considerably exceeds that of the central fasciculi which must contain the fibres contributed to the sympathetic from the cerebro-spinal system; and if to these peripheral fibres we add the branches distributed to the viscera, it seems plain that more fibres must proceed from the ganglia than can possibly be supposed to enter them from the spinal nerves or spinal cord, and that consequently the ganglia must themselves be centres in which nerve-fibres take their rise. It is worthy of remark, that in the frog, according to the observations of the anatomists just named, the central division of the communicating cord greatly exceeds the peripheral in the connections with the upper spinal nerves, but that lower down it gradually diminishes, absolutely as well as in comparison with the peripheral, and at length disappears altogether, so that the fasciculi connected with the 8th and 9th spinal nerves are entirely peripheral in their course.

Difference of communicating cords.

Another circumstance still remains to be noticed respecting the communications of the sympathetic and spinal nerves. It has been long known that in most of these communications there are usually two connecting cords passing between the sympathetic and the spinal nerve; and it has been remarked also by various observers, that these cords contain grey as well as white fasciculi. More recently, however, Todd and Bowman have called attention to the fact that one of the two connecting cords is altogether of the grey kind, consisting of gelatinous fibres, with, as usual, a very few white or tubular fibres mixed with them; and this observation has since been confirmed by Beck. The other cord either is entirely white, or, more commonly, as appears to me, is made up of a white and grey portion running alongside each other. It seems highly probable that the white cords and the white fasciculi of the mixed cords contain the cerebro-spinal fibres which the spinal nerves contribute to the sympathetic, and that the grey cords and fasciculi are contributions from the sympathetic to the spinal nerves. In corroboration of this view, Mr. Beck observes that the grey cords on leaving the ganglia give small branches to the neighbouring vessels, and are reduced in size before joining the spinal nerves. Another interesting fact respecting these communications has been pointed out by the last-named observer somewhat similar to that previously noticed in the frog, namely, that, whilst the grey and white connecting cords are in the thorax of nearly equal size, the grey one relatively increases lower down, and in the pelvis constitutes the sole communication between the sacral ganglia of the sympathetic and the spinal nerves, the white branches from the latter to the sympathetic passing over the sacral ganglia without joining them, to enter the sympathetic plexuses sent to the pelvic viscera.

Connection with the two roots of spinal nerve and spinal cord.

The tubular fibres of each white communicating fasciculus can be traced back to both the anterior and the posterior root of the spinal nerve, and gelatinous fibres from the grey fasciculus may be traced up into the anterior root, and as far as the ganglion of the posterior root, which root has also gelatinous fibres above the ganglion. Whether these central gelatinous fibres proceed from the sympathetic to the spinal cord (possibly to be distributed to its vessels), or are sent from the cord and spinal ganglia to the sympathetic, or pass both ways, is as yet uncertain.

Course of spinal fibres in sympathetic.

As to the further progress of the cerebro-spinal fibres conveyed to the sympathetic by the communicating branches, Valentin has endeavoured to show, that, after joining the main gangliated cord or trunk of the sympathetic, they all take a downward direction, and after running through two or more of the ganglia, pass off in the branches of distribution leaving the trunk considerably lower down than the point where they joined it. He conceives that this arrangement, which he calls "lex progressûs," is proved by experiments on animals, in which he found, that, on irritating different parts of the cerebro-spinal axis, as well as different branches of nerves, the visceral movements which followed bore a relation to the point irritated, which corresponded with the notion of such an arrangement. Volkmann and Bidder, on the other hand, endeavour to show that this opinion cannot be reconciled with the observed anatomical disposition of the fibres; nor will the experimental evidence in its favour apply to the upper part of the sympathetic, where, as Valentin himself admits, motorial fibres must be supposed to run in an upward direction to account for the con-

traction of the pupil which follows section of the cervical part of the sympathetic.

Conclusion as to constitution of sympathetic nerve.

From what has been stated it seems reasonable to conclude that nerve-fibres take their rise in the ganglia both of the cerebro-spinal and sympathetic nerves, and are in both kinds of nerves mixed with fibres of cerebral or spinal origin; that the ganglia are nervous centres which may probably receive through afferent fibres impressions of which we are unconscious and reflect these impressional stimuli upon efferent or motor fibres; that perhaps, even, certain motorial stimuli emanate from them, the movements excited by or through the ganglia being always involuntary, and affecting chiefly the muscular parts of the viscera, the sanguiferous, and perhaps the absorbent vessels; and that, in fine, the chief purpose served in the animal economy by the ganglia and the ganglionic nerve-fibres, whether existing in acknowledged branches of the sympathetic, or contained in other nerves, is to govern the involuntary, and, for the most part, imperceptible movements of nutrition, in so far at least as these movements are not dependent on the brain and spinal cord; for it must not be forgotten that there is unquestionable evidence to prove that the visceral and vascular motions are influenced by nerve-fibres connected with the cerebro-spinal centre.

Have the ganglionic fibres peculiar anatomical characters?

Among various physiologists of consideration, who adopt this view in a more or less modified shape, some have been further of opinion that the fibres of ganglionic origin differ in structure, size, and other physical characters from those which arise in the cerebro-spinal axis. Thus, Remak at one time considered the ganglionic fibres to be exclusively of the kind above described under the name of gelatinous fibres, and these he accordingly proposed to distinguish by the name of "organic," from the tubular, which he regarded as cerebro-spinal fibres; but he has since modified this opinion. Volkmann and Bidder, on the other hand, rejecting the organic fibres of Remak, denying to them indeed the character of nervous elements altogether, endeavour to show that the true ganglionic fibres are identical with the smaller variety of tubular fibres, which especially abound in the branches of the sympathetic—fibres which they hold are characterised by small size and by other peculiarities already mentioned. They contend, that, wherever these smaller fibres occur, whether in the sym-

pathetic or in the branches or the roots of the spinal or cerebral nerves, they are derived from the ganglia, whilst the larger-sized tubular fibres, in the sympathetic as well as in the spinal nerves, are of cerebro-spinal origin. As regards this question, I must confess, that although there is sufficient ground to admit the existence of fibres centering in the ganglia, as well as of others which arise from the cerebro-spinal axis, there does not seem to me to be conclusive evidence to show that peculiar anatomical characters are distinctive of the fibres of different origin; and for aught that has been proved to the contrary, all three varieties of fibres spoken of, large tubular, small tubular, and gelatinous, may arise both in the cerebro-spinal axis and in the ganglia; although it is certainly true that the two latter kinds largely predominate in the sympathetic, and abound in other nerves, or branches of nerves, which appear to receive large contributions from ganglia.

VITAL PROPERTIES OF THE NERVOUS SYSTEM.

Afferent and efferent property of nerves.

The fibres of nerves are endowed with the property of transmitting impressions, or the effect of impressions, from the point stimulated towards their central or their peripheral extremities. One class of fibres conduct towards the nervous centres and are named "afferent," their impressions being "centripetal;" another class of fibres conduct towards their distal extremities, which are distributed in moving parts, and these fibres are named "efferent," whilst their impressions are "centrifugal." Impressions propagated centripetally along the nerves to the brain give rise to sensations, varying according to the nerve impressed, and the objective cause of the impression: stimuli transmitted outwardly, on the other hand, are conveyed to muscles, and excite movements. Motorial stimuli thus passing along efferent nervous fibres may emanate from the brain, as in voluntary and emotional movements, or possibly from some other central part, as in the case of certain involuntary motions; or such stimuli may be applied in the first instance to afferent fibres, by these conducted to the brain or some other central organ, and then "reflected" by the central organ to efferent fibres, along which they are propagated to the muscle or muscles to be moved; and in this case the intervention of the central organ may give rise

Sensation, motion, and reflex action.

to sensation or not, the difference in this respect probably depending on the part of the nervous centre where the reflection takes place.

Office of fibres and cells respectively.

The property of conducting a stimulus or propagating its effects in a determinate direction, belongs to the fibres of the nerves, and in all probability also to the fibrous part of the nervous centre, while it is probable that to the grey matter of the central organs, and especially to its cells or vesicles, is assigned the office of receiving impressions conveyed from without, and presenting them to the conscious mind, of mediating between the mind and the efferent fibres in excitation of the latter by mental stimuli (as in voluntary and emotional acts), of transferring to efferent fibres stimuli conducted to the centre by afferent fibres in the production of reflex movements, and, possibly, of originating purely corporeal stimuli in certain involuntary motions.

Organic influence of nerves.

Many physiologists suppose, that, in addition to these endowments, the nerves have a peculiar power of controlling and regulating the molecular changes and chemical actions which occur in nutrition and in other allied processes; but it may be fairly questioned, whether the effect justly attributable to the nerves in such cases is not produced merely through the influence which they exert over the motions of the minute vessels and contractile tissues concerned in the processes referred to.

Vis nervosa.

The properties above mentioned, of the nerves and nervous centres, have been commonly ascribed to a peculiar force developed in the nervous system, which has received the names of "nervous force," "nervous principle," "nervous influence," and "vis nervosa" (in the largest sense of that term); and whilst some physiologists consider that force as a species of agency altogether peculiar to living bodies, others have striven to identify it with some of the forces known to be in operation in inanimate nature.

Compound and simple nerves.

The greater number of nerves possess both afferent and efferent fibres, and are named compound or moto-sensory, inasmuch as they minister both to sensation and motion. In such compound nerves the two kinds of fibres are mixed together and bound up in the same sheaths; but in the most numerous and best-known examples of this class, the afferent and efferent fibres, though mixed in the trunk and branches of the nerves, are separated at their roots. This is the case in the spinal nerves: these have two roots, an anterior and posterior, both for the most part consisting of

many funiculi, and the posterior passing through a ganglion with which the fibres of the anterior root have no connection. Now it has been ascertained by appropriate experiments on animals, that the anterior root is efferent and contains the motor fibres, and that the posterior is afferent and contains the sensory fibres. The fifth pair of cranial nerves has a sensory root furnished with a ganglion, and a motor root, like the spinal nerves. The glosso-pharyngeal and pneumogastric nerves are also decidedly compound in nature; they are also provided with ganglia at their roots, which involve a greater or less number of their fasciculi; but it has not yet been satisfactorily determined whether in these nerves the fibres which have different properties are collected at the roots into separate bundles, nor how they are respectively related to the ganglia. The sympathetic, as already stated, contains both afferent and efferent fibres.

Simple nerves are such as contain either afferent or efferent fibres only. The olfactory, auditory, and optic are simple afferent and sensory nerves. The third, fourth, and sixth, the facial, the spinal accessory and hypoglossal nerves are generally regarded as examples of simple motor nerves; there is reason to believe, at least, that they are simple and motor in their origin, or as far as their proper fibres are concerned, and that the sensibility evinced by some of them in their branches, is owing to sensory fibres derived from other nerves which join them in their progress.

DEVELOPMENT OF NERVES.

Formation of nerve fibres in fœtal pig.

Schwann found that, in the fœtal pig, three inches long, the commencing nerves consisted of a granular matter indistinctly arranged in pale, longitudinal, coherent fibres, with cell-nuclei contained in or attached to them. Though he has not been able to trace their earliest stages, he infers, from the analogy of the muscular tissue, that these fibres are formed by the coalescence of cells whose nuclei remain, and accordingly supposes that they are tubes filled with finely granular matter (fig. 60′). In a somewhat more advanced stage these pale fibres lose their granular aspect, and acquire the dark contour,—in short, put on the characters of ordinary tubular fibres; and many of them may be seen which have undergone this alteration in a part of their length, whilst the remaining part is still in its primitive condition (fig. 60′, ², ³). The pale fibre is supposed to acquire dark contours in consequence of the formation of the "white substance" or "medullary sheath;" but the mode in which this substance is added to the pale fibre is uncertain. Schwann is inclined to think that it is formed as a secondary deposit on the internal surface of the tubular membrane, which he supposes to exist in the pale fibre as a tube formed by the coalesced walls of the primary cells, and that the

granular matter contained in the pale fibre remains and forms the "primitive band" or "axis." At the same time, as Kölliker suggests, the process may possibly consist in a chemical change of the contained granular matter, by which it is separated into medullary sheath and

Fig 60′.*

axis. Most of the nuclei disappear, but here and there one may be seen on a tubular nerve fibre, situated, according to Schwann, within the tubular membrane, between it and the white substance, as represented in fig. 60′, 5. When first formed, the fibres are of comparatively small size.

In growing parts of the embryo which extend themselves outwards, the more distant portion of the nerves, like that of other continuous structures, must be the last formed; and in the tadpole's tail Schwann observed that the fibres of the more remote and growing nervous branches are smaller and devoid of the dark contour, but are a continuation of fibres (of earlier and older branches) which possess that character; so that the deposition of white substance seems to advance along the fibres in a peripheral direction, the part which is nearer the centre and begins earlier to be formed being also first perfected. As mentioned in a former page (cxciii), little angular knots are observed in the tadpole's tail, where several of these pale fibres meet together; and these Schwann supposes to be remnants of formative cells which had branched out and united with neighbouring cells to form the reticular nerve fibres. Kölliker, who has lately investigated the development of the tissues in batrachian larvæ, is also of opinion that the nervous fibres are formed by the junction of ramified cells; he, however, further concludes from his observations, that the pale fibres which first appear enlarge, that fine tubular fibres are then developed in their substance, either singly or in slender fasciculi of two or three,

In tadpole's tail.

* Development of nervous fibres (after Schwann). 1. Portion of a nerve, exhibiting pale fibres and nuclei, from an embryo pig, four and a half inches in length. 2, 2. Two nerve fibres from a more advanced embryo; the white substance is already formed at one part. 3 and 4. Fibres from the pneumogastric nerve of a calf, in which the nervous matter has been displaced at one part, while the tubular membrane remains. 5. Fibre from the same nerve, exhibiting a nucleus-like corpuscle. Magnified 450 diameters.

and that the latter fibres at first end abruptly, but eventually form loops.

Formation of nerve-cells.

As to the formation of the nerve-cells found in the grey matter of the brain, spinal cord, and ganglia, but very little is known. The first-formed nerve-cells in the embryo may probably be produced by modification of the "embryonic cells," some of which simply enlarge with alteration of their contents, whilst others throw out processes. Valentin conceives that nerve-cells are formed round other cells which serve them as nuclei, their granular contents being first deposited, and afterwards their inclosing cell-wall. Others suppose that they are developed from nuclei like ordinary cells, and then acquire their peculiar contents. The nucleus-like bodies and the pellucid cells of different sizes found in the cortical grey matter of the brain, have been supposed to be successive conditions of the larger granular cells in progress of development; and some physiologists think it not improbable that a constant succession of these cells is produced, to take the place of others that are destroyed and consumed after fulfilling their office. Kölliker supposes that some of the cells increase by division.

Reunion of divided nerves.

The divided ends of a nerve that has been cut across readily reunite, and in process of time true nerve fibres are formed in the cicatrix, and restore the continuity of the nervous structure. The conducting property of the nerve, as regards both motion and sensation, is eventually re-established through the re-united part. Schiff has observed that in the supra-orbital and lingual nerves, the transmission of sensation has occurred before the regeneration of the medulla was perfect, but not until that of the axis-cylinder was accomplished.

BLOOD-VESSELS.

Outline of the sanguiferous system.

THE blood, from which the solid textures immediately derive material for their nourishment, is conveyed through the body by branched tubes named blood-vessels. It is driven along these channels by the action of the heart, which is a hollow muscular organ placed in the centre of the sanguiferous system. One set of vessels, named *arteries*, conduct the blood out from the heart and distribute it to the different regions of the body, whilst other vessels named *veins* bring it back to the heart again. From the extreme branches of the arteries the blood gets into the commencing branches of the veins or revehent vessels, by passing through a set of very fine tubes which connect the two, and which, though not abruptly or very definitely marked off from either, are generally spoken of as an intermediate set of vessels, and by reason of their smallness are called the *capillary* (*i. e.* hair-like) *vessels*, or, simply, *the capillaries*.

The heart.

The conical hollow muscular heart is divided internally into four cavities, two placed at its base, and named auricles, and two occupying the body and apex, named

ventricles. The auricles are destined to receive the returning blood from the great veins, which accordingly open into them, and to deliver it into the ventricles; whilst it is the office of the latter to propel the blood through the body. The ventricles have therefore much thicker and stronger sides than the auricles, and the great arterial trunks lead off from them. Each auricle opens into the ventricle of the same side, but the right auricle and ventricle are entirely shut off from those of the left side by an impervious partition placed lengthwise in the heart.

Course of the blood.

The blood passes out from the left ventricle by the main artery of the body, named the aorta, and is sent through the numerous subordinate arteries, which are branches of that great trunk, to the different parts of the system, then, traversing the capillaries, it enters the veins, and is returned by two great venous trunks, named the superior and inferior venæ cavæ, to the right auricle. In passing from the arteries to the veins the blood changes in colour from red to dark and is otherwise altered in quality; in this condition it is unfit to be again immediately circulated through the body. On returning, therefore, to the right side of the heart, the blood, now dark and venous, must re-acquire the florid hue and other though less obvious qualities of arterial blood before it is permitted to resume its course. For this purpose, being discharged by the right auricle into the right ventricle, it is driven, by the contraction of that ventricle, along the pulmonary artery and its branches to the lungs, where, passing through the capillary vessels of these organs, it is exposed to the influence of the air and undergoes the requisite change, and having now become florid again, it enters the commencing branches of the pulmonary veins, which, ending by four trunks in the left auricle, convey it into that cavity, whence it is immediately discharged into the left ventricle to be sent again along the aorta and through the system as before.

Circulation what.

The blood may thus be considered as setting out from any given point of the sanguiferous system and returning to the same place again after performing a circuit, and this motion is what is properly termed the *circulation* of the blood. Its course from the left ventricle along the aorta, throughout the body, and back by the venæ cavæ to the right ventricle, is named the *greater* or *systemic circulation*, and its passage through the lungs by the pulmonary artery and pulmonary veins from the right to the left side of the

Greater or systemic,

heart, is termed the *lesser* or *pulmonary circulation*; but the blood must go through both the greater and the lesser circulation in order to perform a complete circuit, or to return to the point from which it started. As the vessels employed in the circulation through the lungs have been named pulmonary, so the aorta which conveys the blood to the system at large is named the systemic artery, and the venæ cavæ the systemic veins, whilst the two sets of capillaries interposed between the arteries and veins, the one in the lungs, the other in the body generally, are respectively termed the pulmonary and the systemic capillaries.

Lesser or pulmonary.

Systemic and pulmonic vessels.

The blood flows in the arteries from trunk to branches, and from larger to smaller but more numerous tubes; it is the reverse in the veins, except in the case of the *vena portæ*, a vein which carries blood into the liver. This advehent vein, though constituted like other veins in the first part of its course, divides on entering the liver into numerous branches, after the manner of an artery, sending its blood through these branches and through the capillary vessels of the liver into the efferent hepatic veins to be by them conducted to the inferior vena cava and the heart.

Portal vein.

The different parts of the sanguiferous system above enumerated may be contemplated in another point of view, namely, according to the kind of blood which they contain or convey. Thus the left cavities of the heart, the pulmonary veins, and the aorta or systemic artery, contain red or florid blood fit to circulate through the body; on the other hand, the right cavities of the heart with the venæ cavæ, or systemic veins, and pulmonary artery, contain dark blood requiring to be transmitted through the lungs for renovation. The former or red-blooded division of the sanguiferous system, commencing by the capillaries of the lungs, ends in the capillaries of the body at large; the latter or dark-blooded part commences in the systemic capillaries and terminates in those of the lungs. The heart occupies an intermediate position between the origin and termination of each, and the capillaries connect the dark and the red set of vessels together at their extremities, and serve as the channels through which the blood passes from the one part of the sanguiferous system to the other, and in which it undergoes its alternate changes of colour, since it becomes dark as it traverses the systemic capillaries and red again in passing through those of the lungs.

Vessels of red and vessels of dark blood.

ARTERIES.

Why so named.

These vessels were so named from the notion that they naturally contained air. This error which had long prevailed in the schools of medicine was refuted by Galen, who showed that the vessels called arteries, though for the most part found empty after death, really contained blood in the living body.

Distribution.

Mode of Distribution.—The arteries usually occupy protected situations; thus after coming out of the great visceral cavities of the body they run along the limbs on the aspect of flexion, and not upon that of extension where they would be more exposed to accidental injury.

Division into branches.

As they proceed in their course the arteries divide into branches, and the division may take place in different modes. An artery may at once resolve itself into two or more branches, no one of which greatly exceeds the rest in magnitude, or it may give off several branches in succession and still maintain its character as a trunk. The branches come off at different angles, most commonly so as to form an acute angle with the further part of the trunk, but sometimes a right or an obtuse angle, of which there are examples in the origin of the intercostal arteries. The degree of deviation of a branch from the direction of the trunk was supposed to affect the force of the stream of blood, but Weber maintains, that it can produce little or no effect in a system of elastic tubes maintained, like the arteries, in a state of distension.

Capacity of arterial system increases by branching.

An artery, after a branch has gone off from it, is smaller than before, but usually continues uniform in diameter or cylindrical until the next secession; thus it was found by Mr. Hunter that the long carotid artery of the camel does not diminish in calibre throughout its length. A branch of an artery is less than the trunk from which it springs, but the combined area or collective capacity of all the branches into which an artery divides, is greater than the calibre of the parent vessel immediately above the point of division. The increase in the joint capacity of the branches over that of the trunk is not in the same proportion in every instance of division, and there is at least one case known in which there is no enlargement, namely, the division of the aorta into the common iliac and sacral arteries; still, notwithstanding this and other possible ex-

ceptions, it must be admitted as a general rule that an enlargement of area takes place. From this it is plain, that as the area of the arterial system increases as its vessels divide, the capacity of the smallest vessels and capillaries will be greatest, and as the same rule applies to the veins, it follows that the arterial and venous systems may be represented, as regards capacity, by two cones whose apices (truncated it is true) are at the heart, and whose bases are united in the capillary system. The effect of this must be to make the blood move more slowly as it advances along the arteries to the capillaries, like the current of a river when it flows in a wider and deeper channel, and to accelerate its speed as it returns from the capillaries to the venous trunks.

When arteries unite they are said to anastomose or inosculate. Anastomoses may occur in tolerably large arteries, as those of the brain, the hand and foot, and the mesentery, but they are much more frequent in the smaller vessels. Such inosculations admit of a free communication between the currents of blood, and must tend to promote equability of distribution and of pressure and to obviate the effects of local interruption. Anastomosis or inosculation.

Arteries commonly pursue a tolerably straight course, but in some parts they are tortuous. Examples of this in the human body are afforded by the arteries of the lips and of the uterus, but more striking instances may be seen in some of the lower animals, as in the well-known case of the long and tortuous spermatic arteries of the ram and bull. In very moveable parts like the lips this tortuosity will allow the vessel to follow their motions without undue stretching; but in other cases its purpose is not clear. The physical effect of such a condition of the vessel on the blood flowing along it must be to reduce the velocity, by increasing the extent of surface over which the blood moves, and consequently the amount of impediment from friction; still it does not satisfactorily appear why such an end should be provided for in the several cases in which arteries are known to follow a tortuous course. The same remark applies to the peculiar arrangement of vessels named a "rete mirabile," where an artery suddenly divides into small anastomosing branches which in many cases unite again to reconstruct and continue the trunk. Of such retia mirabilia there are many examples in the lower animals, but, as already remarked, the purpose which they serve Tortuosity of arteries. A rete mirabile, what.

is not apparent. The best known instance is that named the rete mirabile of Galen, which is formed by the intracranial part of the internal carotid artery of the sheep and several other quadrupeds.

Physical properties of arteries.

Physical Properties.—Arteries possess considerable strength and a very high degree of elasticity, being extensible and retractile both in their length and width. When cut across, they present, although empty, an open orifice; the veins, on the other haud, collapse, unless when prevented by connection with surrounding rigid parts.

Sheath.

Structure.—In most parts of the body the arteries are inclosed in a sheath formed of dense areolar tissue, and their outer coat is connected to the sheath by filaments of the same tissue, but so loosely that when the vessel is cut across its ends readily shrink some way within the sheath. The sheath may inclose other parts along with the artery, as in the case of that enveloping the carotid artery, which also includes the internal jugular vein and pneumo-gastric nerve. Some arteries want sheaths, as those for example which are situated within the cavity of the cranium.

Coats.

Independently of this sheath, arteries (except those of minute size whose structure will be afterwards described with that of the capillaries) have been usually described as formed of three coats, named from their relative position, internal, middle, and external; and as this nomenclature is so generally followed in medical and surgical works, and also correctly applies to the structure of arteries so far as it is discernible by the naked eye, it seems best to adhere to it as the basis of our description, although it will be seen, as we proceed, that some of these coats are found by microscopic examination really to consist of two or more strata differing from each other in texture, and therefore reckoned as so many distinct coats by some recent authorities.

Internal coat consists of

Internal coat. This may be raised from the inner surface of the arteries as a fine transparent colourless membrane, elastic but very easily broken, especially in the circular or transverse direction, so that it cannot be stripped off in large pieces. It is very commonly corrugated with very fine and close longitudinal wrinkles, caused most probably by a contracted state of the artery after death. Such is the appearance presented by the internal coat to the naked eye, but by the aid of the microscope it is found to consist of two different structures, namely; 1. A scaly epithelium,

epithelium and

forming the innermost part or lining. This is described by Henle as a thin simple layer of elliptical or irregularly rhombic particles, which are often elongated so as to resemble spindle-shaped fibres. These epithelial elements have round or oval nuclei, which, however, may disappear; indeed the whole structure sometimes becomes indistinct, especially in the larger arteries. 2. One or more layers of a peculiar structure, forming the chief substance of the inner coat, and styled by Henle the "striated," "perforated," or "fenestrated membrane." This consists of a thin and brittle transparent film, forming one or several layers, in which latter case it may be stripped off in small shreds, which have a remarkable tendency to curl in at their upper and lower borders, and roll themselves up as represented in the figure (fig. 61′). The films of membrane are marked by very fine pale streaks, following principally a longitudinal direction, and joining each other obliquely in a sort of network. Henle considers these lines to be reticulating fibres formed upon the membranous layer. This membrane is further remarkable by being perforated with numerous round, oval, or irregularly-shaped apertures of different sizes. In some part of the arteries the perforated membrane is very thin, and therefore difficult to strip off; in other situations it is of considerable thickness, consisting of several layers; but it often happens that the deeper layers of this structure, *i. e.* those farther from the inner surface, lose their membranous character, and degenerate into a mere network of longitudinal anastomosing fibres, quite similar to fine fibres of elastic tissue; indeed there seems much reason to think that the perforated membrane is merely a form or modification of that tissue. These longitudinal reticula- elastic layers.

Fig. 61′.*

* Portion of fenestrated membrane from the crural artery, magnified 200 diameters. (After Henle.) *a*, *b*, and *c*. Perforations.

ting fibres are, however, sometimes spoken of as constituting a distinct coat.

The inner coat may thus be said to be formed of *epithelium* and *elastic layers ;* the latter consisting of elastic tissue under two principal forms, namely, the fenestrated membrane and the longitudinal elastic networks; and these two forms may coexist in equal amount, or one may predominate, the other diminishing or even disappearing altogether.

It is further to be observed, that in the inner coat of the aorta and the larger arteries, in addition to the elements described, lamellæ are found which consist of a clear, homogeneous, or sometimes striated or even fibrillated substance, mostly resembling connective tissue (according to Kölliker) and pervaded by longitudinal elastic networks of varying fineness. Moreover, immediately subjacent to the epithelium, there are often one or more transparent layers which may contain imbedded nuclei, and then look as if formed of coalesced epithelium-cells; or they may be homogeneous and destitute of nuclei, in which case they resemble elastic membranes.

Middle or contractile coat consists of

Middle coat. This consists of distinct fibres disposed circularly round the vessel, and consequently tearing off in a circular direction, although the individual fibres do not form complete rings. The considerable thickness of the walls of the larger arteries is due chiefly to this coat; and in the smaller ones, it is said to be thicker in comparison with the calibre of the vessel. In the largest vessels it is made up of many layers; thus, upwards of forty have been counted in the aorta, twenty-eight in the carotid, and fifteen in the subclavian artery (Räuschel); and shreds of elastic membrane, either finely reticular, or quite similar to the fenestrated membrane of the inner coat, are often found between the layers. The middle coat is of a tawny or reddish-yellow colour, not unlike that of the elastic tissue, but, when quite fresh, it has a softer and more translucent aspect than the last-named tissue. Its more internal part is often described as redder than the rest, but the deeper tint is probably due to staining by the blood after death. The substance of this coat is highly elastic, and was at one time regarded by many, especially among the French anatomists, as being identical in nature with the yellow elastic tissue:

muscular and

but it consists in reality of two kinds of fibres, namely, 1st, pale, translucent, soft, flattened fibres, measuring from $\frac{1}{5000}$th to $\frac{1}{3000}$th of an inch in breadth, presenting here and there a few elongated nucleiform corpuscles, and having

the other characters of the plain variety of muscular fibres, and, 2ndly, fine elastic fibres mixed with the former, and joining together as usual in an irregularly reticular manner. The elastic fibres are accompanied by white fibres of areolar tissue in small quantity, the proportion of which increases with the size of the artery. It is important further to note that the muscular tissue of the middle coat is more pure in the smaller arteries, and that the admixture of other tissues increases in the larger-sized vessels. In accordance with this fact, the vital contractility of the arteries, which depends on their middle coat, is very little marked in those of large size, but becomes much more conspicuous in the smaller branches.

elastic fibres.

External coat. This has usually been described as made up of interwoven filaments of areolar and elastic tissues; but Henle has correctly pointed out that it consists, in the larger arteries, of two layers of different texture, viz. 1st, an internal stratum of genuine elastic tissue, most obvious in arteries of large calibre, and becoming thinner, and at length disappearing in those of small size; 2ndly, an outer layer, consisting of ordinary areolar tissue, in which the filaments are closely interwoven, and in large and middle-sized arteries chiefly run diagonally or obliquely round the vessel; the interlacement of these filaments becomes much more open and lax towards the surface of the artery, where they connect the vessel with its sheath, or with other surrounding parts. This areolar layer is usually of great proportionate thickness in the smaller arteries.

External coat consists of an elastic and an areolar layer.

Some arteries have much thinner coats than the rest, in proportion to their calibre. This is strikingly the case with those contained within the cavity of the cranium, and in the vertebral canal; the difference depends on the external and middle coats, which, in the vessels referred to, are thinner than elsewhere.

Differences.

The coats of arteries receive small vessels, both arterial and venous, named *vasa vasorum*, which serve for their nutrition. The little nutrient arteries do not pass immediately from the cavity of the main vessel into its coats, but are derived from branches which arise from the artery, (or sometimes from a neighbouring artery), at some distance from the point where they are ultimately distributed, and divide into smaller branches within the sheath, and upon the surface of the vessel, before entering its coats. They form a network in the tissue of the external coat, from which a

Vasa vasorum.

few penetrate into the middle coat, and follow the circular course of its fibres; none have been discovered in the internal coat, unless the observations of Jäsche and Arnold are to be trusted, who affirm that they have seen vessels in that situation. Minute venules return the blood from these nutrient arteries, which however they do not closely accompany, and discharge it into the vein or pair of veins which usually run alongside the artery.

Nerves of arteries. Arteries are generally accompanied by larger or smaller nerves; and when, in the operation of tying an artery, these happen to be included along with it in the ligature, great pain is experienced, but the vessel itself, when in a healthy condition, is insensible. Nerves are, nevertheless, distributed to the coats of arteries, probably for governing their contractile movements. The nerves come chiefly from the sympathetic, and in smaller proportion from the cerebro-spinal system. They form plexuses round the larger arteries, and run along the smaller branches in form of fine bundles of fibres, which here and there twist round the vessel, and single nerve fibres have been seen closely accompanying minute arteries. There is less certainty as to the extent and mode of distribution of the nerves in the arterial coats: some observers state, that filaments may be traced as far as the middle coat; and Valentin describes them as ending there in a plexus, whilst Pappenheim and Gerlach state that the nerves terminate in the middle coat, by division and free ends.

Contractility. *Vital properties.—Contractility.* Besides the merely mechanical property of elasticity, arteries are endowed in a greater or less degree with vital contractility, by means of which they can narrow their calibre. This vital contractility, which has doubtless its seat in the soft, pale fibres of the middle coat (seated in middle coat.), does not cause rapid contractions following in rhythmic succession like those of the heart; its operation is, on the contrary, slow, and the contraction produced is of long endurance. Its effect, or its tendency, is to contract the area of the arterial tube, and to offer a certain amount of resistance to the distending force of the blood; and as the contracting vessel will shrink the more, the less the amount of fluid contained in it, the vital contractility would thus seem to adjust the capacity of the arterial system to the quantity and force of the blood passing through it, bracing up the vessels, as it were, and maintaining them in a constant state of tension. In producing this effect, it co-operates with the elasticity of the arterial tubes, but it can be shown that after that property has reached its limit of operation the vital contraction can go further in narrowing the artery. The vital or muscular contractility of the arteries, then, counteracts the distending force of the heart and seems to be in constant operation. Hence it is often named "tonicity," and,

Tonicity.

so far, justly, but at the same time, like the contractility of other muscular structures, it can, by the application of various stimuli, be artificially excited to more vivid action than is displayed in this natural tonic or balanced state; and, on the other hand, it sometimes relaxes more than the habitual degree, and then the vessels yielding to the distending force of the heart become unusually dilated. Such a remission in their contractile force (taking place rather suddenly) is probably the cause of the turgescence of the small vessels of the skin which occurs in blushing, and the arteries of erectile organs are probably affected in the same manner, so as to permit of an augmented flow of blood into the veins or venous cavities when erection begins.

Evidence of contractility of small arteries;

The vital contractility of small-sized arteries is easily demonstrated in the transparent parts of cold-blooded animals. If the point of a needle be two or three times drawn quickly across one of the little arteries (not capillaries) in the web of a frog's foot placed under the microscope, the vessel will be seen slowly to contract, and the stream of blood passing through it becomes smaller and smaller, and, by a repetition of the process, may be made almost entirely to disappear. After persisting in this contracted state for some minutes, the vessel will gradually dilate again to its original size. The same effect may be produced by the application of ice-cold water, and also by galvanism, especially when a rapid succession of shocks is sent through the vessel by means of a coil, as practised by Edward and Ernest H. Weber.* Moreover, if one of the small arteries in the mesentery of a frog or of a small warm-blooded animal, such as a mouse (Poiseuille), be compressed so as to take off the distending force of the blood from the part beyond the point where the pressure is applied, that part will diminish in calibre, at first no doubt from its elasticity, and therefore suddenly, but afterwards slowly. This gradual shrinking of an emptying artery after its elasticity has ceased to operate, may be shown also by cutting out the frog's heart or dividing the main trunks of the vessels: it is obviously due to vital contraction. The contractility of the smaller arteries, as well as its subjection to the influence of the nervous system, is beautifully shown in the experiment of cutting and afterwards stimulating the cervical sympathetic nerve in a cat or rabbit. Immediately after the section, the vessels of the ear become distended with blood from failure of their tonic contraction; but on applying the galvanic stimulus to the upper portion of the nerve they immediately shrink again, and on interrupting the stimulation they relax as before.

of larger arteries.

The contractility of the middle-sized and larger arteries is not so conspicuous, and many excellent observers have failed to elicit any satisfactory manifestation of such property on the application of stimuli to these vessels. Others, however, have observed a sufficiently decided, though by no means a striking degree of contraction slowly to follow mechanical irritation or repeated application of the galvanic wires to these arteries in recently-killed animals. To render this effect more evident, my former colleague, Dr. C. J. B. Williams, adopted a method of experimenting which he had successfully employed to test the irritability of the bronchial tubes. He tied a bent glass tube into the cut end of an artery, and filled the vessel, as well as the bend of the tube, with water; the application of galvanism caused a narrowing of

* Müller's Archiv., 1847, p. 232.

the artery, the reality of which was made manifest by a rise of the fluid in the tube. Contraction is said also to follow the application of chemical stimulants, but as these may directly corrugate the tissue by their chemical action, the evidence they afford is less satisfactory. Cold causes contraction of the larger arteries, according to the testimony of various inquirers; and, as in the smaller arteries, a gradual shrinking in calibre ensues in these vessels, when the distending pressure of the blood is taken off, by the extinction or impairment of the force of the heart on the approach of death. From the experiments of Dr. Parry, it would appear that the contraction thus ensuing, proceeds considerably beyond what would be produced by elasticity alone, and that it relaxes after death, when vitality is completely extinct, so that the artery widens again, to a certain point, at which it is finally maintained by its elasticity.

VEINS.

Veins, their distribution.

Mode of distribution.—The veins are ramified throughout the body, like the arteries, but there are some differences in their proportionate number and size, as well as in their arrangement, which require to be noticed.

In most regions and organs of the body, the veins are more numerous and also larger than the arteries, so that the venous system is altogether more capacious than the arterial, but the proportionate capacity of the two cannot be assigned with exactness. The pulmonary veins form an exception to this rule, for they do not exceed in capacity the pulmonary arteries.

Superficial and deep.

The veins are arranged in a superficial and deep set, the former running immediately beneath the skin, and thence named subcutaneous, the latter commonly accompanying the arteries, and named *venæ comites vel satellites arteriarum.*

Venæ comites.

The large arteries have usually one accompanying vein, and the medium-sized and smaller arteries two; but there are exceptions to this rule: thus, the veins within the skull and spinal canal, the hepatic veins, and the most considerable of those belonging to the bones, run apart from the arteries.

The communications or anastomoses between veins of considerable size, are more frequent than those of arteries of equal magnitude.

Structure of veins.

Structure.—The veins have much thinner coats than the arteries, and collapse when cut across or emptied; whereas, a cut artery presents a patent orifice. Notwithstanding their comparative thinness, however, the veins possess considerable strength, more even, according to some authorities, than arteries of the same calibre. The number of their

coats has been differently reckoned, and the tissues composing them differently described by different writers, and this discrepancy of statement is perhaps partly due to the circumstance that all veins are not perfectly alike in structure. In most veins of tolerable size, three coats may be distinguished, which, as in the arteries, have been named external, middle, and internal.

The *internal coat* is less brittle than that of the arteries, and therefore admits of being more readily peeled off without tearing; but, in other respects, the two are much alike. It consists of an epithelium, a striated lamella containing nuclei, and the usual elastic layers; these occur as dense lamelliform networks of longitudinal elastic fibres, and but seldom as fenestrated membranes. Internal coat.

The *middle coat* is much thinner than that of the arteries, and its muscular tissue has a much larger admixture of areolar tissue. Its fibres are both longitudinal and circular, the one set alternating with the other in layers. The former are well-developed elastic fibres, longitudinally reticulating; the circular layers consist of plain muscular fibres and white fibres of areolar tissue, mixed with a smaller proportion of fine elastic fibres. In medium-sized veins the middle coat contains several successions of the circular and longitudinal layers, but the latter are all more or less connected together by elastic fibres passing through the intervening circular layers. In the larger veins the middle coat is less developed, especially as regards its muscular fibres, but in such cases the deficiency may be supplied by muscularity of the outer coat. According to Kölliker, whom we chiefly follow in this account of the structure of the veins, the middle coat is wanting altogether in most of the hepatic part of the vena cava, and in the great hepatic veins; and even where its thickness is considerable, it is less regularly or not at all disposed in layers, and its muscular fibres are more scanty. The muscularity *of the middle coat* is best marked in the splenic and portal veins; it is apparently wanting in certain parts of the abdominal cava and in the subclavian veins. Middle coat.

The *external coat* is usually thicker than the middle; it consists of areolar tissue and longitudinal elastic fibres. In certain large veins, as pointed out by Remak, this coat contains a considerable amount of plain or non-striated muscular fibres. These are well marked in the whole extent of the abdominal cava, in which they form a longi- External coat.

tudinal network, occupying the inner part of the external coat; and they may be traced into the renal, azygos, and external iliac veins. The muscular fibres *of the external coat* are also well developed in the trunks of the hepatic veins and in that of the vena portæ, whence they extend into the splenic and superior mesenteric.

Peculiarities of veins.

Other veins present peculiarities of structure, especially in respect of muscularity. 1. The muscular tissue of the auricles of the heart is prolonged for some way on the adjoining part of the venæ cavæ and pulmonary veins. 2. The muscular element is largely developed in the veins of the gravid uterus, and is described as being present in all three coats. 3. On the other hand, muscular tissue is wanting in the following veins, viz. *a.* those of the maternal part of the placenta; *b.* most of the veins of the brain and pia mater; *c.* the veins of the retina; *d.* the venous sinuses of the dura mater; *e.* the cancellar veins of the bones; *f.* the venous spaces of the corpora cavernosa. In most of these cases the veins consist merely of an epithelium and a layer or layers of areolar tissue more or less developed; in the corpora cavernosa the epithelium is applied to the trabecular tissue. It may be added that in the thickness of their coats the superficial veins surpass the deep and the veins of the lower limbs those of the upper.

Nutrient vessels and nerves of veins.

The coats of the veins are supplied with nutrient vessels, *vasa vasorum*, in the same manner as those of the arteries. *Nerves* have not been demonstrated in the coats of veins generally; but some observers have succeeded in tracing small branches of nerves on the vena cava inferior, where it passes behind the liver, and filaments, supposed to be nervous, have been seen by Pappenheim on some of the cerebral veins.

Contractility.

Vital properties.—Veins, when in a healthy condition, appear to be almost devoid of sensibility. They possess vital contractility, which shows itself in the same manner as that of the arteries, but is greatly inferior in degree, and much less manifest. The muscular parts of the great veins, near the auricles of the heart, on being stimulated, in recently-killed quadrupeds, exhibit quick and decided contractions, somewhat resembling those of the auricles themselves. Mr. Wharton Jones has discovered a rhythmic pulsation in the veins of the bat's wing, the pulsation occurring from 10 to 12 times in a minute; and it is worthy of note that the muscular fibres of these veins appear to be of the plain or unstriped variety.*

Valves of veins.

Valves.—Most of the veins are provided with valves, a mechanical contrivance beautifully adapted to prevent the reflux of the blood. The valves are formed of semilunar

* Phil. Trans. 1852.

folds of the lining membrane, strengthened by some included fibrous tissue, which project obliquely into the vein. Most commonly two such folds or flaps are placed opposite each other (fig. 62′, A); the convex border of each, which, according to Haller, forms a parabolical curve, is connected with the side of the vein; the other edge is free, and points towards the heart, or at least in the natural direction of the current of the blood along the vessel, and the two flaps obliquely incline towards each other in this direction. Moreover, the wall of the vein immediately above (or nearer the heart than) the curved line of attachment of the valves, is dilated into a pouch or *sinus* on either side (fig. 62′, B *a*), so that when distended with blood or by artificial injection, the vessel bulges out on each side, and thus gives rise to the appearance of a knot or swelling wherever a valve is placed (as in fig. C). From the above description, it is plain that the valves are so directed as to offer no obstacle to the blood in its onward flow, but that when from pressure or any other cause it is driven backwards, the refluent blood, getting between the dilated wall of the vein and the flaps of the valve, will press them inwards until their edges meet in the middle of the channel and close it up.

Fig. 62′.*

The valvular folds are usually placed in pairs as above described; in the veins of the horse and other large quadrupeds three are often found Differences as to valves.

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* Diagrams showing valves of veins. A. Part of a vein laid open and spread out, with two pairs of valves. B. Longitudinal section of a vein, showing the apposition of the edges of the valves in their closed state. C. Portion of a distended vein, exhibiting a swelling in the situation of a pair of valves.

ranged round the inside of the vessel, but this rarely occurs in the human body. On the other hand, the valves are placed singly in some of the smaller veins, and in large veins single valves are not unfrequently placed over the openings of smaller entering branches; also in the right auricular sinus of the heart there is a single crescentic fold at the orifice of the vena cava inferior, and another more completely covering the opening of the principal coronary vein.

Many veins are destitute of valves. Those which measure less than a line in diameter rarely, if ever, have them. Valves are wanting in the trunks of the superior and inferior venæ cavæ, in the trunk and branches of the portal vein, in the hepatic, renal and uterine veins; also in the spermatic veins of the female. In the male, these last-mentioned veins have valves in their course, and in either sex a little valve is occasionally found in the renal vein, placed over the entrance of the spermatic. The pulmonary veins, those within the cranium and vertebral canal, and those of the cancellated texture of bone, as well as the trunk and branches of the umbilical vein, are without valves. Valves are not generally found, and when present are few in number, in the azygos and intercostal veins. On the other hand, they are numerous in the veins of the limbs (and especially of the lower limbs), which are much exposed to pressure in the muscular movements, or from other causes, and have often to conduct the blood against the direction of gravity. No valves are met with in the veins of reptiles and fishes, and not many in those of birds.

CAPILLARY VESSELS.

That the blood passed from the arteries into the veins was of course a necessary part of the doctrine of the circulation, as demonstrated by Harvey; but the mode in which the passage took place was not ascertained until some time after the date of his great discovery. The discovery of the capillary vessels, and of the course of the blood through them, was destined to be one of the first-fruits of the use of the microscope in anatomy and physiology, and was reserved for Malpighi (in 1661), to whose rare sagacity these sciences have been so greatly indebted for their advancement.

Capillaries discovered by Malpighi.

How seen.

When the web of a frog's foot is viewed through a microscope of moderate power (as in fig. 63′), the blood is seen passing rapidly along the small arteries, and thence more slowly through a network of finer channels, by which it is conducted into the veins. These small vessels, interposed between the finest branches of the arteries and the commencing veins, are the capillary vessels. They may be seen also in the lungs or mesentery of the frog and other batrachians, and in the tail and gills of their larvæ: also in the tail of small fishes; in the mesentery of mice or other small quadrupeds; and generally, in short, in the transparent vas-

cular parts of animals which can readily be brought under the microscope. These vessels can also be demonstrated by means of fine injections of opaque-coloured material, not only in membranous parts, such as those above mentioned, but also in more thick and opaque tissues, which can be rendered transparent by drying.

Fig. 63′.*

Usually form networks.

The capillary vessels of a part are most commonly arranged in a network, the branches of which are of tolerably uniform size, though not all strictly equal, and thus they do not divide into smaller branches like the arteries, or unite into larger ones like the veins; but the diameter of the tubes, as well as the shape and size of the reticular meshes which they form, differs in different textures. Their prevalent size in the human body may, speaking generally, be stated at from $\frac{1}{3500}$th to $\frac{1}{2000}$th of an inch, as measured when naturally filled with blood. But they are said to be in some parts considerably smaller, and in others larger than this standard: thus, Weber has measured injected capillaries in the brain, which he found to be not wider than $\frac{1}{4700}$th of an inch, and Henle has observed some still smaller,—in both cases apparently smaller than the natural diameter of the blood corpuscles. The capillaries, however, when deprived of blood, probably shrink in calibre immediately after death; and this consideration, together with the fact that their distension by artificial injection may exceed or fall short of what is natural, should make us hesitate on such evidence to admit the existence of vessels incapable of receiving the red particles of the blood. The diameter of the capillaries of the marrow, or of the medullary membrane, is stated as high as $\frac{1}{1200}$th of an inch. In other parts, their size varies between these extremes: it is small in the lungs, small also in muscle; larger in the skin and mucous membranes. According to Mr. Toynbee, the extreme branches of the arteries and the commencing veins in certain parts of the synovial membranes are connected by

* Capillary blood-vessels in the web of a frog's foot (after Dr. Allen Thomson). The arrows indicate the course of the blood.

loops of vessels, which are dilated at their point of flexure to a greater size even than the vessels which they immediately connect, and such can scarcely with propriety be termed capillaries.

Character of capillary network.

There are differences also in the size or width of the meshes of the capillary network in different parts, and consequently in the number of vessels distributed in a given space, and the amount of blood supplied to the tissue. The network is very close in the lungs and in the choroid coat of the eye, close also in muscle, in the skin, and in most parts of the mucous membrane, in glands and secreting structures, and in the grey part of the brain and spinal cord. On the other hand, it has wide meshes and comparatively few vessels in the ligaments, tendons, and other allied textures. In infants and young persons, the tissues are more vascular than in after-life ; growing parts, too, are more abundantly supplied with vessels than those which are stationary.

The figure of the capillary network is not the same in all textures. In many cases the shape of the meshes seems

Fig. 64'.*

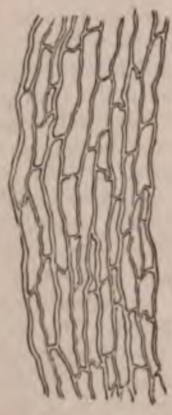


Fig. 65'.†

accommodated to the arrangement of the elements of the tissue in which they lie. Thus in muscle, nerve, and

* Injected capillary vessels of muscle, seen with a low magnifying power.

† Injected capillaries of the skin magnified.

tendon, the meshes are long and comparatively narrow, and run conformably with the fibres and fasciculi of these textures (fig. 64′). In other parts the meshes are rounded or polygonal, with no one dimension greatly predominating (fig. 65′). In the smaller-sized papillæ of the skin and mucous membranes, the vessels of the network are often drawn out into prominent loops.

Structure of capillaries and small vessels.

Structure of the small-sized vessels and capillaries.—The capillary vessels have real coats, and are not mere channels drilled in the tissue which they pervade, as has sometimes been maintained. In various parts they are readily separable from the surrounding substance or parenchyma, as in the brain and retina, and in such cases it is easy to display their independent membranous parietes. The number as well as the structure of their coats, differs according to the size of the vessels. Capillaries of a diameter less than $\frac{1}{2400}$th of an inch have but a single coat, which is formed of simple homogeneous transparent membrane, with nucleiform corpuscles attached at intervals on the outer surface, or inclosed as it were in the substance of the

Fig. 66′.*

membrane (fig. 66′, A). Some of these attached or imbedded corpuscles are round, others oval, the latter usually lying with

* A. Capillary vessels from the pia mater of the sheep, with nucleiform corpuscles (after Henle). Magnified 200 diameters. B. A minute artery, treated with acetic acid, and magnified about 200 diameters (after Henle). *a.* cavity of the vessel and longitudinally disposed nuclei of the primitive membrane; *b, b.* middle coat with elongated corpuscles disposed circularly; *e.* one of these corpuscles; *f.* another seen endwise; *c, c.* external coat, with longitudinal nuclei, *g, g.*

their long diameter parallel to the axis of the vessel. In vessels one or two degrees larger (fig. 66′, B, and 67′), the structure is more complex. The corpuscles of the primitive simple membrane are more numerous and more lengthened; an epithelium exists on the inside of the primitive membrane, and on its outside is added a layer containing nuclei-

Fig. 67′.*

form corpuscles, elongated in a direction across the diameter of the vessel. This layer corresponds with the middle or muscular coat of the arteries, and accordingly, in vessels of somewhat greater size, the characteristic circular fibres of that tunic appear in the layer in question, as well as the nuclei. Outside of all is the areolar coat marked by longitudinal nuclei. In vessels of $\frac{1}{60}$th of an inch in diameter, or even less, the elastic layers of the inner coat may be discovered

* A small artery A, with a corresponding vein B, treated with acetic acid, and magnified 350 diameters (after Kölliker). α, external coat with oblong nuclei; β, nuclei of the transverse muscular tissue of the middle coat (when seen endwise, as at the sides of the vessel, their outline is circular); γ, nuclei of the epithelium-cells; δ, elastic layers of the inner coat.

(fig. 67′, A, δ), in form generally of fenestrated membrane, more rarely of longitudinal reticulating elastic fibres; while the primitive membrane with its longitudinal corpuscles disappears. The small veins, but two or three removes from the capillaries, differ from arteries of corresponding size, chiefly in the inferior development of their muscular tissue.

Vital properties.—From the share which the capillaries take in many vital actions, both healthy and diseased, and especially from the part they have been supposed to play in the process of inflammation, much pains has naturally been bestowed to find out whether they are endowed with vital contractility. There is still, however, a difference of opinion on this question: and, although the weight of evidence is, on the whole, in favour of the existence of this property in the capillaries, it must, nevertheless, be confessed that the proof is by no means so positive and clear as in the case of the small arteries. The chief grounds on which it is affirmed are the two following, which rest on the testimony of various competent observers, who have made the question as to the irritability of the capillaries the subject of experimental inquiry; viz. 1st, That stimulants, such as alcohol, oil of turpentine, pepper, and ice or ice-cold water, applied to the frog's foot or mesentery, cause the capillary vessels to shrink in diameter, and that this contraction is speedily followed by their dilatation beyond their natural capacity; the shrinking of the vessels being attributed to the direct operation of the stimuli on their contractility, and their subsequent dilatation to the temporary exhaustion of that property, consequent on its previous undue excitation. 2ndly, That when the vessels are preternaturally dilated, in the way above described, or by the action of ammonia or common salt, they may, after a time, be made to contract to their usual size by the reapplication of stimuli. **Vital contractility.**

Termination of arteries.—The only known termination of arteries is in veins, and this takes place by means of capillary vessels of some of the forms above described, unless in the maternal part of the placenta, and perhaps, in the interior of erectile organs, to be specially referred to hereafter, in which it has been supposed that small arteries open into wide venous cavities, without the intervention of capillaries. **Known modes of termination of arteries.** Additional modes of termination have, however, been assumed to exist. Thus, it was believed that branches of arteries ended in exhalant vessels, which, in their turn, terminated by open orifices on the skin, on the surface of different internal cavities, or in the areolar tissue; other arterial branches were supposed to be continued into the ducts of secreting glands, and it was, moreover, imagined that, besides the red capillaries, there existed finer vessels, which passed between the arteries and the veins, and from their smallness were able to convey only the colourless part of the blood. **Other modes, assumed or supposed.** The existence of these colourless or "serous" vessels, as they were called (vasa serosa, vasa non rubra), was held, by most authorities, to be universal; by others it was assumed as necessary, at least, in the colourless textures; but these views have now been generally abandoned, although they long prevailed almost without question, and were made the basis of not a few influential doctrines in pathology and practical medicine. Of course it is not denied, that in growing parts there may be capillaries in an incom- **Vasa serosa.**

plete state of development, which admit only the plasma of the blood.

Erectile tissue, what.

Erectile, or cavernous tissue.—By this term is understood a peculiar structure, forming the principal part of certain organs which are capable of being rendered turgid, or erected, by distension with blood. It consists of dilated and freely intercommunicating branches of veins, into which arteries pour their blood, occupying the areolæ of a network formed by fibrous, elastic, and probably contractile bands, named trabeculæ, and inclosed in a distensible fibrous envelope. This peculiar arrangement of the blood-vessels scarcely deserves to be regarded as constituting a distinct texture, though reckoned as such by some writers; it is restricted to a very few parts of the body, and in these is not altogether uniform in character; the details of its structure will, therefore, be considered with the special description of the organs in which it occurs.

DEVELOPMENT OF BLOOD-VESSELS.

Formation of blood-vessels,

The first vessels which appear are formed within the ovum, in the germinal membrane, and the process subsequently goes on in growing parts of the animal body. New vessels, also, are formed in the healing of wounds and sores, in the organisation of effused lymph, in the restoration of lost parts, and in the producton of adventitious growths. Passing over the earlier accounts, the following may serve as an outline of the process, as deduced from the observations of Schwann, on the formation of vessels in the germinal membrane of the incubated egg, and in the growing tail of batrachian larvæ, repeated and confirmed as they have recently been, in the latter case, by Kölliker.

from cells.

The smaller vessels and capillaries originate from nucleated cells similar to those which at first constitute the different parts of the embryo. The cell-wall, or envelope, of these cells, shoots out into slender pointed processes, tending in different directions, so that they acquire an irregularly star-shaped or radiated figure. The prolongations from neighbouring cells encounter one another, and join together by their ends, and the irregularly ramified or reticular cavities thus produced are the channels of rudimentary capillaries. It is in this way, according to Schwann, that the network of vessels begins in the vascular area of the germinal membrane. In growing parts, where new vessels are formed in the vicinity of those already existing, as represented in the adjoining figure (68′), not only do the processes of the stellate cells join those of neighbouring cells, but some of them meet and join with similar pointed processes which shoot out from the sides of neighbouring capillary vessels, and in this manner the new vessels are adopted into the existing system. The junctions of the cells with each other or with capillary vessels are, at first, of great tenuity, and contrast strongly with the central and wider parts of the cells; they appear then to be solid, but they afterwards become pervious and gradually widen, blood begins to pass through them, and the capillary network acquires a tolerably uniform calibre. The original vascular network may become closer by the formation of new vessels in its interstices, and this is effected by similarly metamorphosed cells, arising in the areolæ and joining at various points with the surrounding vessels, and also, according to Kölliker, simply by pointed offshoots from the

existing capillaries stretching across the intervals and meeting from opposite sides, so as when enlarged to form new connecting arches. From observations made on the fœtal membranes of sheep, Mr. Paget has found that the mode of formation of capillaries described by Kölliker in batrachians, holds good also in mammiferous animals.† The simple homogeneous coat of the capillaries is thus formed out of the walls of the coalescing cells; the nuclei on the capillaries seem, however, too numerous to be accounted for merely by the nuclei of these cells. Whilst the finest capillaries retain this simple structure, those that are larger acquire the additional coats already described, and it seems probable that the smaller arteries and veins are formed in the same manner; indeed, it would seem not unreasonable to presume, that the several gradations of structure seen as permanent conditions in vessels of successively larger calibre, may represent the successive steps by which a vessel, having originally the small size and the simple membrane of a fine capillary, increases in width and acquires the complex tunics of a vein or artery. Further observa-

Fig. 68'.*

* Capillary blood-vessels of the tail of a very young frog larva. Magnified 350 diameters. (After Kölliker.) *a*, Capillaries permeable to blood. *b*, Fat granules, attached to the walls of the vessels and concealing nuclei. *c*, Hollow prolongation of a capillary, ending in a point. *d*, A branched cell, containing a nucleus and fat granules, and communicating by three branches with prolongations of capillaries already formed. *e*, Blood corpuscles.

† Supplement to Müller's Physiology, by Baly and Kirkes, 1848, p. 104.

tions, however, are required on this point. Kölliker states, that many vessels which eventually attain a medium size, are originally derived from round cells, which unite in single or double rows and form the primitive simple membranous tube of such vessels, by coalescence of their cavities and walls. He thinks that, in other moderate-sized vessels, the process of formation is the same as in the case of the heart and the large venous and arterial trunks, which are formed not after the manner of the capillaries, but in the way described by most preceding embryologists, namely, by an agglomeration of cells in the situation of the future heart and along the line of the great vessels, forming at first a solid mass, but subsequently becoming hollow within by liquefaction in the centre, whilst the circumferential cells are metamorphosed into the fibres of the heart and the several tissues constituting the coats of the vessels.

Increase of blood-vessels.

The blood-vessels may be said to increase in size and capacity in proportion to the demands made on their service. Thus, as the uterus enlarges in pregnancy, its vessels become enlarged, and when the main artery of a limb is tied, or otherwise permanently obstructed, collateral branches, originally small and insignificant, augment greatly in size, to afford passage to the increased share of blood which they are required to transmit, and by this admirable adaptation of them to the exigency, the circulation is restored. In such cases, an increase takes place in length, as well as in diameter, and accordingly the vessels very commonly become tortuous.

ABSORBENT OR LYMPHATIC SYSTEM.

Consists of lymphatic and lacteal vessels and glands.

Under this head we include not only the vessels specially called lymphatics, together with the glands belonging to them, but also those named lacteal or chyliferous, which form part of the same system, and differ in no respect from the former, save that they not only carry lymph like the rest, but are also employed to take up the chyle from the intestines during the process of digestion and convey it into the blood. An introductory outline of the absorbent system has already been given at page lvi.

Lymphatic vessels exist in all vertebrata.

A system of lymphatic vessels is superadded to the sanguiferous in all classes of vertebrated animals, but such is not the case in the invertebrata; in many of these, the sanguiferous vessels convey a colourless or nearly colourless blood, but no additional class of vessels is provided for conveying lymph or chyle, at least none such has hitherto been detected.

Their distribution.

Distribution.—In man and those animals in which they are present, the lymphatic vessels are found in nearly all the textures and organs which receive blood; the exceptions are few, and with the progress of discovery may yet possibly disappear.

Lymphatics have not as yet been traced in the substance of the brain and spinal cord, though they exist in the membranous envelopes of these parts; nor have they been detected within the eyeball, or in the placenta and fœtal envelopes. It is true that some anatomists have succeeded in injecting what they conceive to be plexuses of lymphatic vessels in the cornea of the eye and in the umbilical cord, but it has not been satisfactorily shown that the injection in these cases had really passed into lymphatics. I have distinctly seen lymphatic vessels, distended with their own lymph, on the surface of an eye which had repeatedly suffered from chronic inflammation; but in this case the vessels appeared to be in or immediately beneath the conjunctival membrane.

In the different regions of the body, and in the several internal viscera, the lymphatics are arranged in a superficial and a deep set. The former run underneath the skin or under the membranous coats immediately enveloping the organs in which they are found; the latter usually accompany the deep-seated blood-vessels. The principal lymphatic vessels of a part exceed the veins in number, but fall short of them in size; they also anastomose or intercommunicate much more frequently than the veins alongside of which they run. Superficial and deep set.

Origin.—This may be either superficial or deep; that is, the lymphatics may arise immediately underneath free surfaces, both external and internal, as for example those of the skin and mucous membranes, or deeply in the substance of organs. Origin is superficial or deep.

In the *superficial* mode of origin, the lymphatics most generally arise in form of networks or plexuses out of which single vessels emerge at various points and proceed directly to lymphatic glands or to join larger lymphatic trunks. These plexuses of origin for the most part consist of several strata, becoming finer as they approach the surface, in respect both of the calibre of the vessels and the closeness of their reticulation. This is shown in figure 69′, which is meant to represent the lymphatic plexuses of the skin. But even the most superficial and finest network is composed of vessels which are larger than the sanguiferous capillaries. They do not open on the surface, as was at one time supposed, and the fluids which they imbibe must pass into them by transudation. Superficial. Plexuses of origin.

In some situations the plexuses of origin have much the appearance Alleged

origin from cells.

of strata of intercommunicating cells, and accordingly the lymphatics have been sometimes described as arising from small cellular cavities. A characteristic example of the appearance referred to is afforded by the intestine of the turtle, after its lymphatics have been injected with mercury; these vessels are then seen to emerge from what has all the appearance of a dense stratum of small rounded cells filled with mercury and lying beneath the surface of the mucous coat. This appearance is, however, to be regarded as in reality produced by the short distended branches of a very close lymphatic network, and transitions are accordingly met with between this and the more usual and regular forms.

Fig. 69′.*

Origin not always plexiform.

But the plexiform mode of origin, though perhaps the most common, is not universal. According to recent observations by Kölliker, the cutaneous lymphatics in the tail of batrachian larvæ branch out in an arborescent manner, and do not unite into a network; their ultimate branches, or, to speak, perhaps, more properly, their commencing radicles, have free but closed ends, not dilated, but running out into fine points.

Lacteals of intestinal villi.

Again, the origin of the lacteals in the intestinal villi is by many held to be peculiar. It was supposed by some that they began by open mouths on the surface of the villi. Lieberkühn conceived that there was a single opening on the summit of each villus leading to a cellular cavity within, which he named "ampulla," and from which a lacteal vessel proceeded. Cruikshank, from what he saw in examining the human villi when they were distended with chyle, was led to believe that each of these processes had on its surface several orifices of commencing lacteals. Others, denying the reality of these apparent openings, still differ in opinion as to the arrangement of the lacteal vessels within the villi. Some, following the opinion of Mascagni and Meckel, describe the commencing lacteals of a villus as arranged in a plexus like its blood-vessels; and this view, which is also supported by recent observations of E. H. Weber, appears to me the most probable. Krause describes and figures a lacteal taking its rise in a villus by several smaller branches, of which some appear to commence by a free extremity, and others join in a plexus. Henle found in each of the villi only a single lacteal branch with a blind dilated extremity, and this view, or one substantially the same, is supported by Herbst and Kölliker. Bruecke, on the other hand, maintains that the lacteals commence as mere interstitial lacunæ, having no proper wall limiting them from the surrounding tissue, and that these lacunar channels pass into vessels with distinct parietes.

Deep origin.

When lymphatics arise deeply, their origin is hidden from view, and the precise mode in which it takes place is not known. There is, however, no good ground for supposing

* Lymphatic vessels of the skin of the breast injected. (After Breschet.) *a*, Superficial, and *b*, deeper plexus. *c*, A lymphatic vessel, which proceeded to the axillary glands.

that it differs in any essential point from what is observed in the more obvious cases already referred to.

Alleged communications with gland-ducts,

It has been sometimes maintained that the lymphatics of glandular organs communicate at their origin with the ducts; but, although it is no uncommon thing for matters artificially injected into the ducts of glands, as, for instance, those of the liver and testicle, to pass into the lymphatics, a careful examination of such cases leads to the conclusion that the injected material does not find its way from the ducts into the lymphatics by any naturally-existing communication, but by accidental rupture of contiguous branches of the two classes of vessels. It seems probable, also, that the communications often held to exist between the commencing lymphatics, both superficial and deep, and capillary blood-vessels, have no better foundation, and that the passage of injection, here also relied on as evidence, is to be accounted for in the same way. A fact mentioned by Kölliker throws light on these alleged communications with sanguiferous capillaries. In investigating the lymphatics of the tadpole's tail with the microscope, that observer not unfrequently noticed that blood-corpuscles got into the lymphatics from the small blood-vessels, and he was able to recognise in the living animal the communications by which they passed. At first he looked on these communications as natural, but, after repeated and careful investigations, he satisfied himself that they were produced accidentally by contusion or some other injury inflicted on the parts.

and with capillary blood-vessels.

Coats of lymphatics.

Structure.—The lymphatic vessels have much thinner coats than the arteries or veins, so thin and transparent indeed that the contained fluid can be readily seen through them. Kölliker describes the fine lymphatics which he saw in the tail of batrachian larvæ as consisting of a simple homogeneous membrane like that of the sanguiferous capillaries, only still more delicate, and like that also presenting nucleiform corpuscles, which were enveloped in groups of fine granules. The vessels were jagged or serrated along both sides with sinuosities and pointed denticulations. According to Henle, the commencing lacteals in the intestinal villi consist also of a simple membrane with elongated nucleiform corpuscles lying in a longitudinal direction.

The medium-sized and larger lymphatics, as well as the thoracic duct, are admitted by all anatomists to have at least two coats, and some assign three, besides an epithelium on the inner surface. Mr. Lane describes three, namely, an internal, which is lined by the epithelium, a middle or fibrous, and an external, analogous to the external or areolar coat of the blood-vessels. The *inner* tunic is thin and transparent, also extensible and elastic, but less so than the other coats, for it is the first to give way when the vessel is unduly distended; its internal surface is covered with a

lacteals which enter a gland are named inferent or afferent vessels (*vasa inferentia* seu *afferentia*) (fig. 70′, *a*, *b*), and those which issue from it efferent vessels (*vasa efferentia*) (*d*, *e*). The afferent vessels, on approaching a gland, divide into many small branches (*b*), which enter the gland, and by their further ramifications, which are more or less involved and tortuous, form within it an intricate plexus (*c*); from this plexus the efferent vessels proceed in form of small branches (*d*), which issue from the gland, and at a little distance beyond it, or before issuing from it, unite into one or more trunks (*e*), usually larger in size but fewer in number than those of the afferent vessels. The afferent and efferent vessels are, according to this view, continuous with each other within the gland, and the cellular cavities described by some anatomists as intervening between them and serving as the medium of their communication, are held to be nothing more than partial dilatations of some branches of the common connecting plexus.

Fig. 70′.*

Hewson's view of the constitution of the lymphatic glands was, till lately, accepted by most anatomists; but the recent researches of Ludwig, Noll, Kölliker, and others, have shown that the structure of these bodies is more complex. The following description is abridged from Kölliker.†

According to recent observers.

A lymphatic gland is covered externally with a coat composed of areolar tissue with the usual elastic fibres and their formative cells; and containing also in certain animals, according to Heyfelder, muscular fibres of the plain variety. This coat is complete except where it gives passage to the efferent lymphatics and the larger blood-vessels; and this part of the gland, which often presents a depression or fissure, may be named the *hilus*. The proper substance of the gland consists of two parts, the *cortical*, and within this the *medullary*. The cortical substance occupies all the superficial part of the gland, except the hilus, and in the larger glands may attain a thickness of from two to three

Cortical and medullary substances.

* A lymphatic gland injected with mercury and dried. (After Hewson.) *a b*, Inferent, *d e*, efferent vessels, communicating with *c*, plexus of lymphatics within the gland.

† Handbuch der Gewebelehre, 2nd edition, 1855.

lines. It is pervaded by numerous septa or partitions passing inwards from the outer coat, and forming a number of loculi or *alveoli*, having a rounded polygonal figure, and measuring from $\frac{1}{8}$th to $\frac{1}{3}$rd of a line in width. The alveoli are filled with a whitish, pulpy matter made up of cells and nuclei, identical in character with the corpuscles of the lymph and chyle; and when this substance is washed out it is found that each alveolus is traversed in all directions by numerous little filaments or trabeculæ and fine lamellæ, which subdivide the space into a great many smaller inter-communicating cavities, and form a sort of *spongy structure*, in the meshes of which the above-mentioned soft matter is contained. Fine capillary blood-vessels also pervade the alveoli, supported by the larger trabeculæ of the spongy texture. The medullary portion of the gland occupies its centre and extends to the surface at the hilus. It is composed of a plexus or of plexuses of lymphatics, which directly communicate with the vasa efferentia, and of the larger ramifications of the blood-vessels of the gland, with an intermediate supporting stroma of areolar tissue. The arteries of the lymphatic glands send their capillaries chiefly but not exclusively to the cortical part, where they run on the trabeculæ of the spongy tissue. The veins end in one or sometimes more large trunks, which issue from the hilus. The relation of the lymphatic vessels to the cavernulated structure of the cortical substance cannot be fully traced by actual inspection; but from careful microscopic investigation, combined with the results of injection of the vessels, Kölliker concludes, with Ludwig and Noll, that the afferent lymphatics, which enter the gland at various points on the surface, open by fine branches into the lacunæ of the spongy structure, and that other fine lymphatics take their rise from these cavities and pass towards the centre or medullary part of the gland to join the central plexus of lymphatics which, as already said, directly lead to the efferent vessel or vessels. The cavities of the spongy structure are not mere dilated vessels, for their internal surface is differently constituted, and, if we regard structure only, they may be considered as having the same relation to the lymphatics, as the lacunæ of the corpora cavernosa have to the blood-vessels. In accordance with this view, it is conceived that the lymph or chyle is poured by the afferent vessels into the cavities of the cortical spongy structure, from which it passes by minute

Blood-vessels.

Lymphatic vessels.

emissary lymphatic vessels into the central lymphatic plexus, and thence by the vasa efferentia out of the gland. The pulpy matter contained in the recesses of the spongy structure is thus conceived to be chyle or lymph, with a very large proportion of its constituent corpuscles; and as the fluid is known to be richer in corpuscles on issuing from the gland than it was on entering it, it is supposed that fresh corpuscles are generated in the glandular cavities from blood-plasma supplied by the numerous capillaries, and that these corpuscles are added to the lymph or chyle which, during its sojourn in the gland, probably undergoes other changes, as stated below.

Use of lymphatic glands.

The lacunar spaces and the plexiform branches of lymphatics within the glands must evidently be collectively more capacious than the afferent or efferent vessels with which they are continuous, and hence the lymph or chyle must move more slowly through them; and while thus detained or delayed in the gland, it is brought into close relation with the blood of the numerous capillaries distributed on the lymphatic lacunæ and plexus, and is thus placed in the most favourable condition for receiving matters by transudation from that fluid, or for yielding up something to the sanguiferous system. It is known that the lymph and chyle contain a greater proportion of fibrin, and are consequently more perfectly coagulable after passing the glands; and it is also observed that the proper corpuscles of the chyle and lymph are most abundant in that which is obtained by puncturing the small branches of lacteals or lymphatics as they issue from the glands. From this latter circumstance, it has been supposed that these corpuscles, though probably also generated elsewhere in the lymphatic and lacteal vessels, are principally produced in the glands, and this view is also in harmony with the above-mentioned results of recent researches into the structure of these organs.

Glands supposed to form fibrin and corpuscles.

Substitutes for glands in fish, reptiles, and birds.

In a gland a large number of plexiform lymphatic vessels or lymphatic spaces, presenting a great extent of surface for the contact of lymph and for the distribution of sanguiferous capillaries, are collected into a compact mass of small compass; but in fishes and reptiles in which there are no lymphatic glands, and in birds, in which there are very few, the purpose served by them appears to be accomplished by means of lymphatic networks occurring in various parts of the body, especially along the course of the larger arteries.* In this lax or expanded form of

* Not only do the lymphatics of many oviparous vertebrata surround the larger arteries in form of close plexuses, but, according to Rusconi, the aorta and mesenteric arteries of the frog and salamander are actually inclosed in wide lymphatic vessels. It has been presumed that in instances such as the last-mentioned, the artery is separated from the lymph by a reflection of the coat of the containing lymphatic vessel, but Rusconi maintains that such is not invariably the case. See his work entitled Riflessioni sopra il Systema Linfatico dei Rettili. Pavia, 1845, in which will also be found, besides many interesting obser-

lymphatic gland, as it might be considered, capillary blood-vessels are distributed on the lymphatic plexus, but the different elements are not compacted into a solid mass.

Termination.—The absorbent system discharges its contents into the veins at two points, namely at the junction of the subclavian and internal jugular veins of the left side by the thoracic duct, and in the corresponding part of the veins of the right side by the right lymphatic trunk. The openings, as already remarked, are guarded by valves. It sometimes happens that the thoracic duct divides, near its termination, into two or three short branches, which open separately, but near each other; more rarely, a branch opens into the vena azygos, indeed the main vessel has been seen terminating in that vein. Again, it is not uncommon for larger branches which usually join the thoracic duct, to open independently in the vicinity of the main termination; and this is more apt to happen with the branches which usually unite to form the right lymphatic trunk. By such variations the terminations in the great veins are multiplied, but still they are confined in man to the region of the neck; in birds, reptiles, and fish, on the other hand, communications take place between the lymphatics of the pelvis, posterior extremities and tail, and the sciatic or other considerable veins of the abdomen or pelvis.

Terminations of lymphatics in venous system at two points.

Variations.

Additional terminations in oviparous vertebrata.

The alleged terminations of lymphatics in various veins of the abdomen, described by Lippi as occurring in man and mammalia, have not been met with by those who have since been most engaged in the prosecution of this department of anatomical research, and accordingly his observations have generally been either rejected as erroneous, or held to refer to deviations from the normal condition.* But, while such (extra-glandular) terminations in other veins than those of the neck have not been generally admitted, several anatomists of much authority have maintained that the lacteals and lymphatics open naturally into veins within the lymphatic glands. This latter opinion, which has been strenuously advocated by Fohmann in particular, is based on a fact well known to every one conversant with the injection of the vessels in question, namely, that the quicksilver usually employed for that purpose, when it has entered a gland by the inferent lymphatics, is apt to

Alleged additional terminations in man.

vations on the lymphatic system of reptiles, an account of his improved method of injecting these vessels.

* In a communication inserted in Müller's Archiv. for 1848, p. 173, Dr. Nuhn, of Heidelberg, affirms the regular existence of these abdominal terminations, and refers to three instances which he met with himself. In two of these, the lymphatics opened into the renal veins, and in the other into the vena cava.

pass into branches of veins within the gland, and thus finds its way into the large venous trunks in the neighbourhood, in place of issuing by the efferent lymphatic vessels. But, although it, of course, cannot be doubted that, in such cases, the mercury gets from the lymphatics into the veins, no one has yet been able to perceive the precise mode in which the transmission takes place, and, looking to the circumstances in which it chiefly occurs, it seems to be more probably owing to rupture of contiguous lymphatics and veins within the glands, than to a natural communication between the two classes of vessels in that situation.

Lymphatic hearts.

Lymphatic hearts.—Some years ago, Müller and Panizza, nearly about the same time, but independently of each other, discovered that the lymphatic system of reptiles is furnished, at its principal terminations in the venous system, with pulsatile muscular sacs, which serve to discharge the lymph into the veins. These organs, which are named lymph-hearts, have now been found in all the different orders of reptiles. In frogs and toads two pairs have been discovered, a posterior pair, situated in the sciatic region, which pour their lymph into a branch of the sciatic or of some other neighbouring vein, and an anterior more deeply-seated pair, placed over the transverse process of the third vertebra, and opening into a branch of the jugular vein. The parietes of these sacs are thin and transparent, but contain muscular fibres of the striated kind, disposed spirally, and decussating in different layers, as in the blood-heart. In their pulsations they are quite independent of the latter organ, and are not even synchronous with each other. In salamanders, lizards, serpents, tortoises, and turtles, only a posterior pair have been discovered, which, however, agree in all essential points with those of the frog. In the goose, and in other species of birds belonging to different orders, Panizza discovered a pair of lymph-sacs opening into the sacral veins,* and Stannius has since found that these sacs have striated muscular fibres in their parietes; but, although this observer, in some cases, exposed them in the living bird, he was not able to discover any pulsation or spontaneous movement in them.†

Development of lymphatics.

Development of lymphatic vessels. — Kölliker states that he has observed the formation of lymphatics from ramified cells in the tails of young salamander-larvæ. He states that the process takes place nearly in the same manner as in the case of the sanguiferous capillaries already described; the only notable difference being, that whilst the growing lymphatics join the ramified cells, and thus extend themselves, their branches very rarely anastomose or become connected by communicating arches. New-formed lymphatics have been injected in adhesions between inflamed serous membranes.

SEROUS MEMBRANES.

Serous membranes, where found.

The serous membranes are so named from the nature of the fluid with which their surface is moistened. They line cavities of the body which have no outlet, and the chief

* Osservazioni antropo-zootomico-fisiologiche. Pavia, 1830, pp. 65 and 67.

† Müller's Archiv., 1843, p. 449.

examples of them are, the peritonæum, the largest of all, lining the cavity of the abdomen; the two pleuræ and pericardium in the chest; the arachnoid membrane in the cranium and vertebral canal; and the tunica vaginalis surrounding each of the testicles within the scrotum.

Form and arrangement.—In all these cases the serous membrane has the form of a closed sac, one part of which is applied to the walls of the cavity which it lines, the *parietal* portion; whilst the other is reflected over the surface of the organ or organs contained in the cavity, and is therefore named the *reflected* or *visceral* portion of the membrane. Hence the viscera in such cavities are not contained within the sac of the serous membrane, but are really placed behind or outside of it; merely pushing inwards, as it were, the part of the membrane which immediately covers them, some organs receiving in this way a complete, and others but a partial and sometimes very scanty investment. Parietal and visceral portions.

In passing from one part to another, the membrane frequently forms folds which in general receive the appellation of ligaments, as, for example, the folds of peritonæum passing between the liver and the parietes of the abdomen, but which are sometimes designated by special names, as in the instances of the mesentery, meso-colon, and omentum. Folds or serous ligaments.

The peritonæum, in the female sex, is an exception to the rule that serous membranes are perfectly closed sacs, inasmuch as it has two openings by which the Fallopian tubes communicate with its cavity. Female peritonæum perforated.

A serous membrane sometimes lines a fibrous membrane, as where the arachnoid lines the dura mater, or where the serous layer of the pericardium adheres to its outer or fibrous part. Such a combination is often named a *fibro-serous* membrane. Fibro-serous membranes.

The inner surface of a serous membrane is free, smooth, and polished; and, as would occur with an empty bladder, the inner surface of one part of the sac is applied to the corresponding surface of some other part; a small quantity of fluid, usually not more than merely moistens the contiguous surfaces, being interposed. The parts situated in a cavity lined by serous membrane can thus glide easily against its parietes or upon each other, and their motion is rendered smoother by the lubricating fluid. Internal or free surface.

The outer surface most commonly adheres to the parts which it lines or covers, the connection being effected by means of areolar tissue, named therefore "subserous," which, External or attached surface.

when the membrane is detached, gives to its outer and previously adherent surface a flocculent aspect. The degree of firmness of the connection is very various: in some parts, the membrane can scarce be separated; in others, its attachment is so lax as to permit of easy displacement. The latter is the case in the neighbourhood of the openings through which abdominal herniæ pass, and accordingly when such protrusions of the viscera happen to take place, they usually push the peritonæum before them in form of a hernial sac.

Arachnoid. The visceral portion of the arachnoid membrane is in some measure an exception to the rule of the outer surface being everywhere adherent; for in the greater part of its extent, it is thrown loosely round the parts which it covers, a few fine fibrous bands being the sole bond of connection; and a quantity of serous fluid is interposed, especially in the vertebral canal and base of the cranium, between it and the pia mater, which is the membrane immediately investing the brain and spinal cord.

Physical properties. *Structure and properties.*—Serous membranes are thin and transparent, so that the colour of subjacent parts shines through them. They are tolerably strong, with a moderate degree of extensibility and elasticity. They consist of, 1st,

Structure. a simple layer of scaly epithelium already described and figured (fig. 15′), which, however, is ciliated on the serous membrane lining the ventricles of the brain of the embryo, and on the part of the peritonæum which covers the fimbriated end of the Fallopian tubes; 2ndly, next to the epithelium, and supporting it, an exceedingly fine lamella of *simple* or *homogeneous membrane*, named *basement membrane* by Todd and Bowman, who, as far as I know, were the first distinctly to point it out as a constituent of the serous membranes; its existence generally in these membranes, has since, however, been questioned; 3dly, one or more layers of fine but dense areolar tissue. This consists, as usual, of bundles of white filaments mixed with elastic fibres: the former, when there are two or more layers, take a different direction in the different planes; the latter unite into a network, and, in many serous membranes, as remarked by Henle, are principally collected into a reticular layer at the surface of the strata of areolar tissue, or, to speak more precisely, immediately beneath the basement membrane. The constituent areolar tissue of the serous membrane is of course continuous with the usually more lax *subserous areolar tissue* connecting the membrane to the subjacent parts.

Blood-vessels ending in a capillary network with comparatively wide meshes, together with plexuses of lymphatic vessels, pervade the subserous tissue and the areolar tissue which forms part of the serous membrane, but do not penetrate its basement membrane or epithelium. Plexuses of fine nervous fibres have been described by several anatomists, in or immediately beneath the serous membranes of various regions: nevertheless it would seem, that when in a healthy condition these membranes possess little or no sensibility: they are altogether devoid of vital contractility. Vessels and nerves.

Fluid.—The internal surface of serous cavities is moistened and lubricated with a transparent and nearly colourless fluid, which in health exists only in a very small quantity. This fluid, which is doubtless derived from the blood-vessels of the membrane, is commonly understood to be similar in constitution to the serum of the blood, and such unquestionably is generally its nature when it accumulates in unusually large quantity, as in dropsical effusions; the chief or only difference being in its proportion of albumen, which is, for the most part, smaller than in blood-serum. But it was long since remarked by Hewson (and a similar opinion seems to have been held by Haller and Monro), that the fluid obtained from the serous cavities of recently-killed animals coagulates spontaneously, and thus resembles the lymph of the lymphatic vessels, and, we may add, the liquor sanguinis or plasma of the blood, the coagulation being, of course, due to fibrin. Hewson found that the coagulability diminished as the quantity of the fluid increased. In confirmation of Hewson's statement, I may mention that I have always found the fluid obtained from the peritonæal cavity of rabbits to coagulate spontaneously in a greater or less degree. Hewson made his observations on the fluid of the peritonæum, pleura, and pericardium, in various animals, viz., bullocks, dogs, geese, and rabbits. The subject needs further examination, for we know that the small quantity of liquid which may generally be obtained from the human pericardium after death is not observed to contain a coagulum nor to coagulate on exposure.* Fluid of serous cavities.

When a serous membrane is inflamed, it has a great tendency to throw out coagulable lymph (or fibrin) and serum, the two constituents of the blood-plasma, the former chiefly adhering to the inner surface of the membrane, whilst the latter gathers in its cavity. The coagulable lymph spread over the surface, in form of a "false membrane," as it is called, or agglutinating the opposed surfaces of the serous sac and causing adhesion, becomes pervaded by blood-vessels, and in process of time converted into areolar tissue. Effects of inflammation.

Breaches of continuity in these membranes are readily repaired, and the new-formed portion acquires all the characters of the original tissue. Reparation.

* See Hewson's Works, published by the Sydenham Society, p. 157, with some important remarks in notes xviii. and lxviii., by the editor, Mr. Gulliver.

SYNOVIAL MEMBRANES.

Distinguished from serous membranes by their secretion.

Resembling serous membranes in general form and structure, the synovial membranes are distinguished by the nature of the secretion which lubricates their surface, for this is a viscid glairy fluid resembling the white of an egg, and thence named *synovia*.

Use.

These membranes line the cavities of joints and are interposed between moving parts in certain other situations; being in all cases intended to lessen friction and thereby facilitate motion. They are composed of a scaly epithelium which, according to Henle, may consist of several strata, and a layer of dense areolar tissue pervaded by vessels and attached by tissue of the same kind to the parts beneath.

Three forms.

The different synovial membranes of the body are referred to three classes, viz. *articular*, *vesicular*, and *vaginal*.

Articular synovial membranes.

1. *Articular synovial membranes*, or *Synovial capsules of joints*. These line and by their synovial secretion lubricate the cavities of the diarthrodial articulations, that is, those articulations in which the opposed surfaces glide on each other. In these cases the membrane may be readily seen covering internally the surface of the capsular or other ligaments which bound the cavity of the joint, and affording also an investment to tendons or ligaments which happen to pass through the articular cavity, as in the instance of the long tendon of the biceps muscle in the shoulder-joint. On approaching the articular cartilages the membrane passes over their margins, and, becoming much more firmly adherent, terminates after advancing but a little way on their surface. This, as already explained (page cii), is the condition in the adult, but in the fœtus the membrane, closely adhering, is continued over the whole surface of the cartilage, so that it would seem to become obliterated or absorbed in consequence of pressure or friction when the joint comes to be exercised. The blood-vessels in and immediately underneath the membrane are sufficiently manifest in most parts of the joint. They advance but a little way upon the cartilages, forming a vascular zone round the margin of each, named "circulus articuli vasculosus," in which they end by loops of vessels dilated at the bent part greatly beyond the diameter of ordinary capillaries. In the fœtus, according to Mr. Toynbee, these vessels, like

the membrane itself, advance further upon the surface of the cartilage.

In several of the joints, folds of the synovial membrane, often containing more or less fat, pass across the cavity; these have been called synovial or mucous ligaments. Other processes of the membrane simply project into the cavity at various points. These are very generally cleft into fringes at their free border, upon which their blood-vessels, which are numerous, are densely distributed. They often contain fat, and then, when of tolerable size, are sufficiently obvious; but many of them are very small and inconspicuous. The fringed vascular folds of the synovial membrane were described, by Dr. Clopton Havers (1691), under the name of the *mucilaginous glands*, and he regarded them as an apparatus for secreting synovia. Subsequent anatomists, while admitting that, as so many extensions of the secreting membrane, these folds must contribute to increase the secretion, have, for the most part, denied them the special character of glands, considering them rather in the light of a mechanical provision for occupying spaces which would otherwise be left void in the motion of the joints. Havers's view has, however, been revived by Mr. Rainey,* who finds that the processes in question exist in the bursal and vaginal synovial membranes as well as in those of joints, wherever, in short, synovia is secreted. He states that their blood-vessels have a peculiar convoluted arrangement, differing from that of the vessels of fat, and that the epithelium covering them, "besides inclosing separately each packet of convoluted vessels, sends off from each tubular sheath secondary processes of various shapes, into which no blood-vessels enter." Kölliker, who has since taken up the inquiry, also finds that fringed membranes exist in all joints and synovial sheaths, as well as in most synovial bursæ, and that they consist of vascular tufts of the synovial membrane, covered by epithelium, and now and then containing fat-cells and more rarely isolated cartilage cells. He also observed the curious "non-vascular secondary processes," described by Mr. Rainey, the larger of which, he says, consist of fibres of areolar tissue in the centre, sometimes containing cartilage cells, and a covering of irregularly thickened epithelium.

Folds and fringes.

2. *Vesicular* or *Bursal synovial membranes*, *Synovial bursæ*, *Bursæ mucosæ*.—In these the membrane has the form of a simple sac, interposed, so as to prevent friction, between two surfaces which move upon each other. The synovial sac in such cases is flattened and has its two opposite sides in apposition by their inner surface which is free and lubricated with synovia, whilst the outer surface is attached by areolar tissue to the moving parts between which the sac is placed.

Synovial bursæ.

In point of situation the bursæ may be either deep-seated or subcutaneous. The former are for the most part placed between a muscle or its tendon and a bone or the

Deep.

* Proceedings of the Royal Society, May 7th, 1846.

exterior of a joint, less commonly between two muscles or tendons : certain of the bursæ situated in the neighbourhood of joints not unfrequently open into them. The subcutaneous bursæ lie immediately under the skin, and are found in various regions of the body interposed between the skin and some firm prominence beneath it. The large bursa, situated over the patella, is a well-known example of this class, but similar, though smaller bursæ are found also over the olecranon, the malleoli, the knuckles, and various other prominent parts. It must, however, be observed, that, among these subcutaneous bursæ, some are reckoned which do not always present the characters of true synovial sacs, but look more like mere recesses in the subcutaneous areolar tissue, larger and more defined than the neighbouring areolæ, but still not bounded by an evident synovial membrane. Their walls are formed of common connective tissue, and possess no epithelium. These have been looked on as examples of less developed structure, forming a transition between the areolar tissue and perfect synovial membrane.

Subcutaneous.

3. *Vaginal Synovial membranes* or *Synovial sheaths.*— These are intended to facilitate the motion of tendons as they glide in the fibrous sheaths which bind them down against the bones in various situations. The best-marked examples of such fibrous sheaths are to be seen in the hand and foot, and especially on the palmar aspect of the digital phalanges, where they confine the long tendons of the flexor muscles. In such instances one part of the synovial membrane forms a lining to the osseo-fibrous tube in which the tendon runs, and another part is reflected at each end upon the tendon and affords it a close investment. The space between the parietal and reflected portions of the membrane is lubricated with synovia and crossed obliquely by one or more folds or duplications of the membrane, in some parts inclosing elastic tissue. These are named "fræna," and pass from the one part of the membrane to the other.

Synovial sheaths.

Fræna.

Nature of synovia.

Synovia.—As already stated, this is a viscid transparent fluid ; it has a yellowish or faintly reddish tint, and a slightly saline taste. According to Frerichs the synovia of the ox consists of 94·85 water, 0·56 mucus and epithelium, 0·07 fat, 3·51 albumen and extractive matter and 0·99 salts. If a drop of synovial fluid is examined microscopically, it is found to contain (in addition to fat-molecules and epithelium cells) small, granular corpuscles, bearing a close resemblance to the

pale corpuscles of the blood. It is doubtful whether these bodies have a special nature and purpose, or whether they are merely transitory forms of epithelium-particles.

MUCOUS MEMBRANES.

These membranes, unlike the serous, line internal passages, and other cavities which open on the surface of the body, as well as various recesses, sinuses, gland-ducts and receptacles of secretion, which open into such passages. They are habitually subject to the contact of foreign substances introduced into the body, such as air and aliment, or of various secreted or excreted matters, and hence their surface is coated over and protected by mucus, a fluid of a more consistent and tenacious character than that which moistens the serous membranes. General nature and situation.

The mucous membranes of several different or even distant parts are continuous, and, with certain unimportant reservations, to be afterwards explained, they may all be reduced to two great divisions, namely, the *gastro-pulmonary* and the *genito-urinary*. The former covers the inside of the alimentary and air-passages as well as the less considerable cavities communicating with them. It may be described as commencing at the edges of the lips and nostrils where it is continuous with the skin, and proceeding through the nose and mouth to the throat, whence it is continued throughout the whole length of the alimentary canal to the termination of the intestine, there again meeting the skin, and also along the windpipe and its numerous divisions as far as the air-cells of the lungs, to which it affords a lining. From the nose the membrane may be said to be prolonged into the lachrymal passages, extending up the nasal duct into the lachrymal sac and along the lachrymal canals until, under the name of the conjunctival membrane, it spreads over the fore part of the eyeball and inside of the eyelids, on the edges of which it encounters the skin. Other offsets from the nasal part of the membrane line the frontal, ethmoidal, sphenoidal and maxillary sinuses, and from the upper part of the pharynx a prolongat ion etends on each side along the Eustachian tube to line that passage and the tympanum of the ear. Besides these there are offsets from the alimentary membrane to line the lachrymal, salivary, pancreatic, and biliary ducts, and the gall-bladder. Two principal divisions. Gastro-pulmonary.

The *genito-urinary* membrane invests the inside of the Genito-urinary.

urinary bladder and the whole track of the urine in both sexes, from the interior of the kidneys to the orifice of the urethra, also the seminal ducts and vesicles in the male, and the vagina, uterus, and Fallopian tubes in the female.

Mammary.

The mucous membranes lining the ducts of the mammary glands, being unconnected with either of the above-mentioned great tracts, have sometimes been enumerated as a third division, and the number might of course be multiplied, were we separately to reckon the membranes prolonged from the skin into the ducts of the numerous little glands which open on the surface of the body.

Attachment.

The mucous membranes are attached by one surface to the parts which they line or cover by means of areolar tissue, named "submucous," which differs greatly in quantity as well as in consistency in different parts. The connection is in some cases close and firm, as in the cavity of the nose and its adjoining sinuses; in other instances, especially in cavities subject to frequent variation in capacity, like the gullet and stomach, it is lax and allows of some degree of shifting of the connected surfaces. In such cases as the last-mentioned the mucous membrane is accordingly thrown into folds when the cavity is narrowed by contraction of the exterior coats of the organ, and of course these folds, or *rugæ*, as they are named, are effaced by distension. But in certain parts the mucous membrane forms permanent folds, not capable of being thus effaced, which project conspicuously into the cavity which it lines. The best-marked example of these is presented by the *valvulæ conniventes* seen in the small intestine. These, as is more fully described in the special anatomy of the intestines, are crescent-shaped duplicatures of the membrane, with connecting areolar tissue between their laminæ, which are placed transversely and follow one another at very short intervals along a great part of the intestinal tract. The chief purpose of the valvulæ conniventes is doubtless to increase the surface of the absorbing mucous membrane within the cavity, and it has also been supposed that they serve mechanically to delay the alimentary mass in its progress downwards. A mechanical office has also been assigned to a series of oblique folds of a similar permanent kind, though on a smaller scale, which exist within the cystic duct.

Folds or rugæ.

Permanent folds,—valvulæ conniventes.

Physical properties.

Physical properties.—In most situations the mucous mem-

branes are nearly opaque or but slightly translucent. They possess no great degree of tenacity and but little elasticity, and hence are readily torn by a moderate force. As to colour, they cannot be said intrinsically to have any, and when perfectly deprived of blood they accordingly appear white or at most somewhat grey. The redness which they commonly exhibit during life, and retain in greater or less degree in various parts after death, is due to the blood contained in their vessels, although it is true that after decomposition has set in, the red matter of the blood, becoming dissolved, transudes through the coats of the vessels, and gives a general red tinge to the rest of the tissue. The degree of redness exhibited by the mucous membrane after death is greater in the fœtus and infant than in the adult. It is greater too in certain situations; thus, of the different parts of the alimentary canal it is most marked in the stomach, pharynx, and rectum. Again, the intensity of the tint, as well as its extent, is influenced by circumstances accompanying or immediately preceding death. Thus the state of inflammation or the local application of stimuli to the membrane, such as irritant poisons, or even food, in the stomach, is apt to produce increased redness; and all the mucous membranes are liable to be congested with blood and suffused with redness when death is immediately preceded by obstruction to the circulation, as in cases of asphyxia, and in many diseases of the heart.

Cause of red colour.

Structure.—A mucous membrane is composed of the corium and epithelium. The *epithelium* covers the surface, and has already been described (p. lxiv.). The membrane which remains after removal of the epithelium is named the *corium*, as in the analogous instance of the true skin. The corium may be said to consist of a *fibro-vascular layer*, of variable thickness, bounded superficially or next the epithelium by an extremely fine transparent lamella, named *basement membrane* by Bowman, and *primary membrane*, *limitary membrane* and *membrana propria* by others who have described it. It must be explained, however, that these two constituents of the corium cannot in all situations be separated from each other, nor indeed can the presence of both be proved by actual demonstration in all parts of the mucous membranes.

Consist of corium and epithelium.

The *basement membrane* is best seen in parts where the mucous membrane is raised into villous processes or where

Basement membrane, how seen.

it forms secreting crypts or minute glandular recesses, such as those which abound in the stomach and intestinal canal. On teasing out a portion of the gastric or intestinal mucous membrane under the microscope, some of the tubular glands are here and there discovered which are tolerably well cleared from the surrounding tissue, and their parietes are seen to be formed of a thin pellucid film, which is detached from the adjoining fibro-vascular layer, the epithelium perhaps still remaining in the inside of the tube, or having escaped as the case may be. The fine film referred to is the basement membrane. It may by careful search be seen too on the part of the corium situated between the orifices of the glands, and on the villi, when the epithelium is detached, although it cannot be there separated from the vascular layer. In these parts it manifestly forms a superficial boundary to the corium, passing continuously over its eminences and into its recesses, defining its surface, and supporting the epithelium. Where villi and tubular glands are wanting, and where the mucous membrane, more simply arranged, presents an even surface, as in the tympanum and nasal sinuses, the actual presence of a fine film or basement membrane cannot be demonstrated. In such situations it may possibly have originally existed as a constituent of the corium, and have been obliterated or rendered inconspicuous in consequence of subsequent modifications.

Nature of the basement membrane.

The basement membrane, as already said, forms the peripheral boundary of the corium; it is in immediate connection with the epithelium, which it supports, and in the production of which it is supposed to have probably some share. By its under surface it more or less closely adjoins the fibro-vascular layer. The vessels of the latter advance close up to the basement membrane, but nowhere penetrate it; the delicate film of which it consists is indeed wholly extra-vascular. In respect of structure the membrane in question seems perfectly homogeneous, but marks resembling the nuclei of epithelium cells are sometimes seen disposed evenly over its surface, and some observers, considering these as forming an integrant part of the membrane, have looked on them as so many reproductive centres from which new epithelium particles are generated. Mr. Bowman, on the other hand, considers these objects as nuclei belonging to the undermost and as it were nascent epithelium cells, which have remained adherent to the really simple basement membrane.

The *fibro-vascular layer* of the corium is composed of vessels both sanguiferous and lymphatic, with fibres of areolar tissue, and, in many parts, of non-striated muscular fibres, variously disposed. The nerves also which belong to the mucous membrane are distributed in this part of its structure. Fibro-vascular layer of corium.

The vessels exist universally in mucous membranes, except in that which covers the anterior surface of the cornea; there the epithelium and basement membrane are present, but, in the adult, no vessels except at the border. The branches of the arteries and veins dividing in the submucous tissue send smaller branches into the corium, which at length form a network of capillaries in the fibro-vascular layer. This capillary network lies immediately beneath the basement membrane, advancing with that membrane into the villi and papillæ to be presently described, and surrounding the tubes and other glandular recesses, into which it is hollowed. The lymphatics also form plexuses, the finest of which lie at the surface, probably just below the basement membrane; their arrangement generally, as well as in the villi, has been already described. Its vessels.

The fibres of areolar tissue which enter into the formation of the corium are arranged in interlacing bundles; but their amount is very different in different parts. In some situations, as in the gullet, bladder, and vagina, the fibrous constituent is abundant, and extends throughout the whole thickness of the fibro-vascular layer, forming a continuous and tolerably compact web, and rendering the mucous membrane of those parts comparatively stout and tough. In the stomach and intestines, on the other hand, where the membrane is more complex, and at the same time weaker in structure, the areolar tissue is in small proportion; its principal bundles follow and support the blood-vessels, deserting, however, their finer and finest branches which lie next the basement membrane; and accordingly there exists, next, and for a little depth below this membrane, a stratum of the corium in which very few if any filaments of areolar tissue are seen. In this superficial stratum the sanguiferous capillaries and lymphatics are spread out amidst a soft granular matter, with a few corpuscles, mostly resembling cell-nuclei and granular cells. Here too, as well as deeper in the corium, a few bodies are seen having the appearance of fusiform cells. The villi present the same internal structure as this superficial stratum, and appear Fibres of corium.

to be prolongations of it; they contain muscular fibres of the plain variety placed longitudinally round their lacteal vessels.

Papillæ and villi.

The free surface of the mucous membranes is in some parts plain, but in others is beset with little eminences named papillæ and villi. The *papillæ* are best seen on the tongue; they are small processes of the corium, mostly of a conical or cylindrical figure, containing blood-vessels and nerves, and covered with epithelium. Some are small and simple, others larger and compound or cleft into secondary papillæ. They serve various purposes; some of them no doubt minister to the senses of taste and touch, many appear to have chiefly a mechanical office, while others would seem intended to give greater extension to the surface of the corium for the production of a thick coating of epithelium. The *villi* are most fully developed on the mucous coat of the small intestines. Being set close together like the pile or nap of cloth, they give to the parts of the membrane which they cover, the aspect usually denominated "villous." They are in reality little elevations or processes of the superficial part of the corium, covered with epithelium, and containing blood-vessels and lacteals, which are thus favourably disposed for absorbing nutrient matters from the intestine. The more detailed description of the papillæ and villi belongs to the special anatomy of the parts where they occur.

Alveolar structure of some mucous membranes.

In some few portions of the mucous membrane the surface is marked with fine ridges which intersect each other in a reticular manner, and thus inclose larger and smaller polygonal pits or recesses. This peculiar character of the surface of the membrane, which might be called "alveolar," is seen very distinctly in the gall-bladder, and on a finer scale in the vesiculæ seminales; still more minute alveolar recesses with intervening ridges may be discovered with a lens on the mucous membrane of the stomach.

Glands.

Glands of mucous membranes.—Many, indeed most of the glands of the body, pour their secretions into the great passages lined by mucous membranes; but there are certain small glands which may be said to belong to the membrane itself, inasmuch as they are found in numbers over large tracts of that membrane, and yield mucus, or special secretions known to be derived from particular portions of the membrane. Omitting local peculiarities the glands referred to may be described as of three kinds, viz. :—

1. *Tubular follicles.*—These are minute tubes formed by recesses or inversions of the basement membrane, and lined with epithelium. They are usually placed perpendicularly to the surface, and often very close together, and they constitute the chief substance of the mucous membrane in those parts where they abound, its apparent thickness depending on the length of the tubes, which differs considerably in different regions. The tubes open by one end on the surface; the other end is closed, and is either simple or loculated, or even cleft into two or more branches. The tubular follicles are abundant in the stomach, in the small intestines, where they are comparatively short and known as the crypts of Lieberkühn, and in the large intestine. They exist also in considerable numbers in the mucous membrane of the uterus. Tubular glands.

Saccular follicles.—These are small cavities of a rounded shape, found in various parts of the mucous membrane, but neither their structure, nor the nature or purpose of their secretion, has yet been sufficiently made out. Some of them are habitually closed, but are supposed to open occasionally to give issue to their secretions; others probably have constantly open orifices. Examples of the former variety are found in the agminated and solitary glands of the intestines. Saccular glands.

3. *Small compound glands.*—Under this head are here comprehended minute but still true compound glands of the vesicular or racemose kind, with single branched ducts of various lengths, which open on different parts of the membrane. Numbers of these, yielding a mucous secretion, open into the mouth and windpipe. They have the appearance of small solid bodies, often of a flattened lenticular form, but varying much both in shape and size, and placed at different depths below the mucous membrane on which their ducts open. The glands of Brunner, which form a dense layer in the commencing part of the duodenum, are of this kind. Compound glandules.

Nerves.—The mucous membranes are supplied with nerves, and endowed with sensibility; but the proportion of nerves which they receive, as well as the degree of sensibility which they possess, differs very greatly in different parts. As to the mode of distribution and termination of their nerves, there is nothing to be said beyond what has been already stated in treating of the nerves in general. Nerves of mucous membrane.

Secretion.—Mucus is a more or less viscid, transparent, or slightly Mucus.

turbid fluid, of variable consistency. It is somewhat heavier than water, though expectorated mucus is generally prevented from sinking in that liquid by entangled air-bubbles. Examined with the microscope, it is found to consist of a fluid, containing solid particles of various kinds, viz., 1. Epithelium particles detached by desquamation; 2. Mucus corpuscles, which are bodies resembling much the pale corpuscles of the blood; 3. Nucleated cells, with more or less ample envelope, and apparently in a state of transition from the condition of mucus corpuscles to that of epithelium particles. The viscidity of mucus depends on the liquid part, which contains in solution a peculiar substance, named by the chemists *mucin*. This ingredient is precipitated and the mucus rendered turbid by the addition of water or a weak acid, but it may be partly redissolved in an excess of water, and completely so in a strong acid. This mucin is soluble in alkalies, and its acid solutions are not precipitated by ferrocyanide of potassium. Little can, of course, be expected from a chemical analysis of a heterogeneous and inseparable mixture of solid particles with a liquid solution, such as we find in mucus, which is, moreover, subject to differences of quality according to the part of the mucous membrane whence it is derived. Examined thus in the gross, however, the nasal mucus has been found to yield water, mucin, alcohol-extract with alkaline lactates, water-extract with traces of albumen and a phosphate, chlorides of sodium and potassium, and soda. Fat has been obtained by analysis of pulmonary mucus, reputed healthy.

Reproduction.

Regeneration.—The reparatory process is active in the mucous membranes. Breaches of continuity occasioned by sloughing, ulceration, or other causes, readily heal. The steps of the process have been examined with most care in the healing of ulcers of the large intestine, and in such cases it has been found that the resulting cicatrix becomes covered with epithelium, but that the tubular follicles are not reproduced.

THE SKIN.

THE skin consists of the cutis vera or corium, and the cuticle or epidermis.

Consists of corium and epidermis; nature of latter.

The *epidermis*, *cuticle*, or *scarf skin*, belongs to the class of epithelial structures, the general nature of which has been already considered. It forms a protective covering over every part of the true skin, and is itself quite insensible and non-vascular. The thickness of the cuticle varies in different parts of the surface, measuring in some not more than $\frac{1}{240}$th, and in others from $\frac{1}{24}$th to $\frac{1}{12}$th of an inch. It is thickest in the palms of the hands and soles of the feet, where the skin is much exposed to pressure, and it is not improbable that this may serve to stimulate the subjacent true skin to a more active formation of epidermis; but the difference does not depend solely on external causes, for it is well marked, even in the fœtus.

Epidermis composed of cells.

Structure.—The cuticle is made up of flattened cells agglutinated together in many irregular layers. These cells arise in a blastema, which is poured out on the surface of the true skin. They at first contain nuclei with soft and moist contents, and, by successive formations beneath them, are gradually pushed to the free surface, become flattened in their progress into thin irregular scales, for the most part lose their nuclei, and are at last thrown off by desquamation. Kölliker finds that the deepest cells are elongated in figure, and placed perpendicularly on the surface of the corium, like the particles of columnar epithelium; these perpendicular cells generally form one, but in some places two or three strata; above them are cells of a more rounded shape. As the cells change their form, they undergo chemical and physical changes in the nature of their contents; for those in the deeper layers contain a soft, opaque, granular matter, soluble as well as their envelope, in acetic acid, whilst the superficial ones are transparent, dry, and firm, and are not affected by that acid. It would seem as if their contents were converted into a horny matter, and that a portion of this substance is employed to cement them together. The more firm and transparent super-

ficial part of the epidermis may be separated from the deeper, softer, more opaque, and recently-formed part, which constitutes what is called the Malpighian layer, or *rete mucosum*.

Cutaneous pigment.

Many of the cells of the cuticle contain pigment, and often give the membrane more or less of a tawny colour, even in the white races of mankind; the blackness of the skin in the negro depends entirely on the cuticle. The pigment is contained principally in the cells of the deep layer or rete mucosum, and appears to fade as they approach the surface, but even the superficial part possesses a certain degree of colour. More special details respecting the pigment have been already given (page lxxix).

Relation of cuticle to cutis.

The under or attached surface of the cuticle is moulded on the adjoining surface of the corium, and, when separated by maceration or putrefaction, presents impressions corresponding exactly with the papillary or other eminences, and the furrows or depressions of the true skin; the more prominent inequalities of the latter are marked also on the outer surface of the cuticle, but less accurately. Fine tubular prolongations of the cuticle sink down into the ducts of the sweat glands, and are often partially drawn out from their recesses when the cuticle is detached, appearing then like threads proceeding from its under surface.

Composition of cuticle.

Chemical composition.—The cuticle consists principally of a substance peculiar to the epithelial and horny tissues, and named *keratin*. This horny matter is insoluble in water at ordinary temperatures, and insoluble in alcohol. It is soluble in the caustic alkalies. In composition, it is analogous to the albuminoid principles, but with a somewhat larger proportion of oxygen; like these, it contains sulphur. Besides keratin, the epidermis yields, on analysis, a small amount of fat, with salts, and traces of the oxides of iron and manganese. The tissue of the cuticle readily imbibes water, by which it is rendered soft, thick, and opaque, but it speedily dries again, and recovers its usual characters.

Corium—how attached.

The *true skin*, *cutis vera*, *derma*, or *corium*, is a sentient and vascular texture. It is covered and defended, as already explained, by the insensible and non-vascular cuticle, and is attached to the parts beneath by a layer of areolar tissue, named "subcutaneous," which, excepting in a few parts, contains fat, and has therefore been called also the "panniculus adiposus." The connection is in many parts loose and movable, in others close and firm, as in the palmar surface of the hand and the sole of the foot, where the skin

is fixed to the subjacent fascia by numerous stout fibrous bands, the space between being filled with a firm padding of fat. In some regions of the body the skin is moved by striated muscular fibres, which may be unconnected to fixed parts, as in the case of the orbicular muscle of the mouth, or may be attached beneath to bones or fasciæ, like the other cutaneous muscles of the face and neck, and the short palmar muscle of the hand.

Structure.—The corium consists of a *fibro-vasuclar layer* which is supposed to be bounded at the surface next the cuticle, by a fine homogeneous *basement membrane* or *membrana propria*, like the corresponding part of the mucous membrane. No such superficial film can, it is true, be raised from the corium, but from its distinct presence in small gland-ducts, which are continuous with the corium, and from the fact that a thin homogeneous membrane lies between the commencing cutis and cuticle in the embryo, it is presumed that a limitary membrane of this sort ought to be reckoned as an element of the corium, although, as in the analogous case of the mucous membrane, it cannot be shown to exist over the whole surface. The *fibro-vascular* part is made up of an exceedingly strong and tough framework of interlaced fibres, with blood-vessels and lymphatics. The fibres are chiefly of the white variety, such as constitute the chief part of the fibrous and areolar tissues, and are arranged in stout interlacing bundles, except at and near the surface, where the texture of the corium becomes very fine. With these are mixed yellow or elastic fibres, which vary in amount in different parts, but in all cases are present in much smaller proportion than the former kind. The interlacement becomes much closer and finer towards the free surface of the corium, and there the fibres can be discovered only by teazing out the tissue. The most superficial layer is composed of a transparent matrix, homogeneous, or nearly so, in which nuclei are embedded; and, according to Mr. Huxley, such indications of lamination, as may be seen, are simply the commencement of the conversion of this tissue into areolar connective tissue. Towards the attached surface, on the other hand, the texture becomes much more open, with larger and larger meshes, in which clumps of fat and the small sudatory glands are lodged, and thus the fibrous part of the skin becoming more and more lax and more mixed with fat, blends gradually with the subcutaneous areolar tissue to

Structure of corium.

which it is allied in elementary constitution. Plain muscular fibres are distributed in the tissue of the corium wherever hairs occur; and their connection with the latter will be afterwards explained. Muscular fibres of the same kind are found in the subcutaneous tissue of the scrotum, penis, perineum, and areola of the nipple, as well as in the nipple itself. The bundles of these fibres join to form reticular superimposed layers, which are separated from the parts beneath by a stratum of simple lax areolar tissue, but towards the surface they are immediately applied to the corium. In the areola they are disposed circularly.

Thickness of corium.

In consequence of this gradual transition of the corium into the subjacent tissue, its thickness cannot be assigned with perfect precision. It is generally said to measure from a quarter of a line or less to nearly a line and a half. As a general rule, it is thicker on the posterior aspect of the head, neck, and trunk, than in front; and thicker on the outer than on the inner side of the limbs. The corium, as well as the cuticle, is remarkably thick on the soles of the feet and palms of the hands. The skin of the female is thinner than that of the male.

Reticular and papillary layers.

For convenience of description it is not unusual to speak of the corium as consisting of two layers, the "reticular" and "papillary." The former, the more deeply-seated, takes no part in the construction of the papillæ, but contains in its meshes hair follicles, cutaneous glands, and fat. The latter is divided into papillæ, and receives only the upper portion of the hair-follicles and glands, together with the terminal expansion of the vessels and nerves.

Furrows on surface.

The free surface of the corium is marked in various places with larger or smaller furrows, which also affect the superjacent cuticle. The larger of them are seen opposite the flexures of the joints, as those so well known in the palm of the hand and at the joints of the fingers. The finer furrows intersect each other at various angles, and may be seen almost all over the surface; they are very conspicuous on the back of the hands. These furrows are not merely the consequence of the frequent folding of the skin by the action of muscles or the bending of joints, for they exist in the fœtus. The wrinkles of old persons are of a different nature, and are caused by the wasting of the soft parts which the skin covers. Fine curvilinear ridges, with intervening furrows, mark the skin of the palm and sole; these

are caused by ranges of the papillæ, to be immediately described.

Papillæ. *Papillæ.*—The free surface of the corium is beset with small eminences thus named, which seem chiefly intended to contribute to the perfection of the skin as an organ of touch, seeing that they are highly developed where the sense of touch is exquisite, and *vice versâ.* They serve also to extend the surface for the production of the cuticular tissue, and hence are large-sized and numerous under the nail. The papillæ are large, and in close array on the palm and palmar surface of the fingers, and on the corresponding parts of the foot (fig. 71′). There they are ranged in lines forming the curvilinear ridges seen when the skin is still covered with its thick epidermis. They are of a conical figure, rounded or blunt at the top, and sometimes cleft into two or more points, when they are named compound papillæ. They are received into corresponding pits on the under surface of the cuticle. In structure they resemble the superficial layer of the cutis generally, and consist of a homogeneous tissue, presenting only faint traces of fibrillation, together with a few fine elastic fibres. On the palm, sole, and nipple, where they are mostly of the compound variety, they measure from $\frac{1}{200}$th to $\frac{1}{100}$th of an inch in height. In the ridges, the larger papillæ are placed sometimes in single but more commonly in double rows, with smaller ones between them, that is, also on the ridges, for there are none in the intervening grooves. These ridges are marked at short and tolerably regular intervals with notches, or short transverse furrows, in each of which, about its middle, is the minute funnel-shaped orifice of the duct of a sweat gland (fig. 72′). In other parts of the skin endowed with less sensibility, the papillæ are smaller, shorter, fewer in number, and irregularly scattered. On the face they are reduced to from $\frac{1}{800}$th to $\frac{1}{300}$th of an inch; and here they at parts disappear altogether, or are replaced by slightly elevated reticular ridges. In parts where they are naturally small, they

Fig. 71′.*

* Papillæ, as seen with a microscope, on a portion of the true skin, from which the cuticle has been removed. (After Breschet.)

often become enlarged by chronic inflammation round the margin of sores and ulcers of long standing, and are then much more conspicuous. Fine blood-vessels enter the papillæ, forming either simple capillary loops in each, or dividing into two or more capillary branches, according to the size of the papilla, which turn round in form of loops and return to the veins. The nerves of the papillæ will be presently considered along with the tactile corpuscles.

Fig. 72′.*

Vessels.

Blood-vessels and lymphatics.—The blood-vessels divide into branches in the subcutaneous tissue, and, as they enter the skin, supply capillary plexuses to the fat clumps, sweat glands, and hair follicles. They divide and anastomose still further as they approach the surface, and at length, on reaching it, form a dense network of capillaries, with rounded polygonal meshes, as previously represented in fig. 65′. Fine branches are sent into the papillæ, as already mentioned. The lymphatics are abundant in some parts of the skin, as on the scrotum and round the nipple; whether they are equally so in all parts may be doubted. They form networks, which become finer as they approach the surface, and communicate underneath with straight vessels, and these, after a longer or a shorter course, join larger ones or enter lymphatic glands.

Nerves.

Nerves.—Nerves are supplied in very different proportions to different regions of the skin, and according to the degree of sensibility. They pass upwards towards the papillary surface, where they form plexuses, of which the meshes become closer as they approach the surface, and the constituent branches finer, so that the latter come at last to consist of only one or two primitive fibres. The fibres also become more attenuated the further they proceed towards their final destination. In the finest and most superficial part of the plexus, the ultimate fibres, or at least some of them, undergo actual division. In certain parts of the

* Magnified view of a portion of epidermis, showing the ridges caused by the papillæ beneath, with the short transverse furrows and the openings of the sudoriferous ducts. (After Breschet.)

skin nerve-fibres terminate in Pacinian bodies, as already described; others are seen to enter the papillæ, where, notwithstanding recent careful investigations by several able anatomists, their ultimate mode of distribution must still be regarded as uncertain. The following is a summary of the present state of the question:

R. Wagner and Meissner distinguish two kinds of papillæ, the nervous and the vascular; the latter being supplied with blood-vessels but receiving no nerves, whilst each of the former receives one or more nerve-fibres and contains one of the peculiar bodies discovered by Meissner and named "tactile corpuscles," *corpuscula tactûs*. Kölliker admits that some papillæ which receive blood-vessels have no nerves, but he denies that nerves are supplied exclusively to papillæ which

Nerves of papillæ.

Tactile corpuscles.

Fig. 73′.*

contain tactile corpuscles, maintaining that they may also pass into some which are destitute of such corpuscles. As to the nature of the tactile corpuscles; they were regarded by Wagner as a peculiarly organised apparatus subservient to the sense of touch, and he described

* Papillæ from the skin of the hand, freed from the cuticle and exhibiting the tactile corpuscles. Magnified 350 diameters. A. Simple papilla with four nerve-fibres and two terminal loops. *a.* Tactile corpuscle; *b.* nerves; *c, c.* loops. B. Papilla treated with acetic acid. *a.* Cortical layer with cells and fine elastic filaments; *b.* tactile corpuscle with transverse nuclei; *c.* entering nerve with neurilemma; *d.* nerve-fibres winding round the corpuscle. C. Papilla viewed from above so as to appear as a cross section. *a.* cortical layer; *b.* nerve-fibre; *c.* sheath of the tactile corpuscle containing nuclei; *d.* central substance of the same. (After Kölliker.)

them as oval-shaped bodies made up of superimposed saccular laminæ and comparable in appearance to a miniature fir-cone. He also described the nerve-fibres of the papillæ as terminating in the corpuscles, either simply or after division into fine filaments. Kölliker, on the other hand, after a careful examination of the subject, is led to conclude that the bodies in question are a not very important modification of a structure more or less common to all the papillæ. He states that in the papillæ generally the centre or axis consists of a more homogeneous connective tissue than the outer or cortical part, and is in many cases marked off from the latter by a sort of sheath of elastic tissue, the elements of which are disposed circularly, and he conceives that the tactile corpuscles are merely a variety of this general structure, in which the elastic elements for the most part retain their primary condition of fusiform nucleated cells extending into fibres and having elongated nuclei. These elements being ranged horizontally around the central clear substance, in rather close order, give rise to a defined object in the centre of the papilla having a laminated and fir-cone like aspect. Respecting the distribution of the nerve-fibres Kölliker states that for the most part two, but sometimes four, five or six, or even only one, may enter a papilla; that they run up in a waving manner to the tactile corpuscle, but do not penetrate into it, although they sometimes form two or three coils round it. He is disposed to think that the nerve-fibres finally join together in loops, but by no means denies that some may end singly.

Chemical composition of corium.

Chemical composition.—The corium being composed chiefly of white fibrous tissue, has a corresponding chemical composition. It is, accordingly, in a great measure, resolved into gelatin by boiling, and hence, also, its conversion into leather by the tanning process.

Development of cutis;

Development of the Cutis.—The cutis consists at first of cells which may in animals be traced back to the first formative cells of the embryo. Many of them become changed into connective tissue; others into vessels and nerves; and a third portion into fat-cells and elastic fibres.

Progressive development takes place from within outwards, so that the papillæ are formed latest: and the development consists not only in the production of new cells, but in the growth of the elements already deposited.

of cuticle.

The *Cuticle* at first differs in no point from the cutis, but consists of the earliest formative cells. Their subsequent metamorphoses and the modes of production of new cells have not been accurately determined; but it appears probable that there may be more ways than one, some of the cells being produced endogenously, and others from free nuclei upon the surface of the corium.

Nails and *Hairs.*—The nails and hairs are growths of the epidermis, agreeing essentially in nature with that membrane; their epidermic tissue is destitute of vessels and nerves, and separable from the cutis.

Parts of a nail.

Nails.—The posterior part of the nail which is concealed in a groove of the skin is named its "root," the uncovered part is the "body," which terminates in front by the "free edge." A small portion of the nail near the root,

named from its shape the *lunula*, is whiter than the rest. This appearance is due partly to some degree of opacity of the substance of the nail at this point and partly to the skin beneath being less vascular than in front.

Matrix of nail.

The part of the corium to which the nail is attached, and by which in fact it is secreted or generated, is named the matrix. This portion of the skin is highly vascular and thickly covered with large vascular papillæ. Posteriorly the matrix is bounded by a crescentic groove or fold, deep in the middle but getting shallower at the sides, which lodges the root of the nail. The small lighter-coloured part of the matrix next the groove and corresponding with the lunula of the nail, is covered with papillæ having no regular arrangement, but the whole remaining surface of the matrix situated in front of this, and supporting the body of the nail, is marked with longitudinal and very slightly diverging ridges formed by rows of papillæ. The cuticle, advancing from the back of the finger, becomes attached to the upper surface of the nail near its posterior edge, that is, all round the margin of the groove in which the nail is lodged; in front the cuticle of the point of the finger becomes continuous with the under surface of the nail a little way behind its free edge.

Structure of nails.

The nail, like the cuticle, is made up of scales derived from flattened cells. The oldest and most superficial of these are the broadest and hardest, but at the same time very thin and irregular, and so intimately and confusedly connected together that their respective limits are scarcely discernible. But the youngest cells, which are those situated at the root and under surface, are softer and of a rounded or polygonal shape, and still retain their nuclei. The deepest layer differs somewhat from the others, in having its cells elongated, and arranged perpendicularly. In chemical composition the nails resemble epidermis; but, according to Mulder, they contain a somewhat larger proportion of carbon and sulphur.

Mode of growth.

The growth of the nail is effected by a constant generation of cells at the root and under surface. Each successive series of these cells being followed and pushed from their original place by others, lose their nuclei, and become flattened into dry, hard, and inseparably coherent scales. By the addition of new cells at the posterior edge the nail is made to advance, and by the apposition of similar particles to its under surface it is maintained of due thickness. The

nail being thus merely an exuberant part of the epidermis, the question whether that membrane is continued underneath it loses its significance.

Reproduction of nails. When a nail is thrown off by suppuration, or pulled away by violence, a new one is produced in its place, provided the matrix remains.

Parts of a hair. *Hairs.*—A hair consists of the root, which is fixed in the skin, the shaft or stem, and the point. The *stem* is generally cylindrical, but often more or less flattened, sometimes it is grooved along one side, and therefore reniform in a cross section: when the hair is entire it becomes gradually smaller towards the point. The length and thickness vary greatly in different individuals and races of mankind as well as in different regions of the body. Light-coloured hair is usually finer than black.

Cortical scales. The stem is covered with a coating of finely-imbricated scales, the projecting serrated edges of which give rise to a series of fine waved transverse lines, which may be seen with the microscope on the surface of the hair. Within this scaly covering is a *fibrous substance* which in all cases constitutes the chief part and often the whole of the stem; but in many hairs the axis is occupied by a substance of a different nature, called the *medulla* or *pith*, for which reason the surrounding fibrous part is often named "cortical," although this term is more properly applied to the superficial coating of scales abovementioned.

Structure of the fibrous substance. The fibrous substance is translucent, with short longitudinal opaque streaks of darker colour intermixed. It may be broken up into straight, rigid, longitudinal fibres, which, when separated, are found to be flattened, broad in the middle, where they measure $\frac{1}{4400}$th of an inch in breadth, and pointed at each end, with dark and rough edges. These fibres may be resolved into flattened cells of a fusiform outline; they are mostly transparent, or marked with only a few dark specks. The colour of the fibrous substance is caused by oblong patches of pigment-granules, and generally diffused colouring matter of less intensity. Very slender elongated nuclei are also discovered by means of reagents, whilst specks or marks of another description in the fibrous substance are occasioned by minute irregularly-shaped cavities containing air. These air-lacunules are best seen in white hairs, in which there is no risk of deception from pigment-specks. Viewed by transmitted light they are dark, but brilliantly white by reflected light. When a white hair has been boiled in water, ether, or oil of turpentine, these cavities become filled with

fluid, and are then quite pellucid; but when a hair which has been thus treated is dried, the air quickly finds its way again into the lacunæ, and they resume their original aspect.

Medulla.

The medulla or pith, as already remarked, does not exist in all hairs. It is wanting in the fine hairs over the general surface of the body, and is not commonly met with in those of the head. When present it occupies the centre of the shaft and ceases towards the point. It is more opaque and deeper-coloured than the fibrous part; in the white hairs of quadrupeds it is opaque and white. It seems to be composed of little clumps or clusters of cells, differing in shape, but generally angular, and containing minute particles, some resembling pigment granules, and others like very fine fat granules, but really for the most part air-particles. The whole forms a continuous dark mass along the middle of the stem, interrupted at parts for a greater or less extent. In the latter case, the axis of the stem at the interruptions may be fibrous like the surrounding parts, or these intervals may be occupied by a clear, colourless matter; and, according to Henle, some hairs present the appearance of a sort of canal running along the axis and filled in certain parts with opaque granular matter, and in others with a homogeneous transparent substance.

Hair follicle.

The *root* of the hair is lighter in colour and softer than the stem; it swells out at its lower end into a bulbous enlargement or knob, and is received into a recess of the skin named the *hair follicle*, which, when the hair is of considerable size, reaches down into the subcutaneous fat. The follicle, which receives near its mouth the opening ducts of one or more sebaceous glands, is somewhat dilated at the bottom, to correspond with the bulging of the root; it consists of an outer coat continuous with the corium (fig. 73′, *d*, *d*), and an epidermic lining (*b*, *c*), continuous with the cuticle. The outer or dermic coat is thin but firm, and consists of three layers. The most external is formed of areolar tissue, without any elastic fibres, but with numerous long fusiform nuclei. It is highly vascular, and possesses nervous fibrils. It is the thickest of the three strata, and determines the form of the follicle. The most internal layer is a transparent, structureless membrane, in which neither acids nor alkalis bring out nuclei or cells; it corresponds with the membrana propria or basement membrane of analogous structures. Between the two is a delicate layer composed of circular fibres, and extending from the base of

Dermic coat and cuticular lining of follicle.

the follicle as high as the entrance of the sebaceous glands. It contains neither vessels nor nerves; and its fibres resemble, in the possession of elongated nuclei, those of plain muscular tissue, but their real nature is doubtful. The epidermic lining adheres closely to the root of the hair, and commonly separates, in great part, from the follicle, and abides by the hair, when the latter is pulled out; hence it is sometimes named the "root-sheath." It consists of an outer, softer, and more opaque stratum (fig. 73′, *c*, *c*), next

Fig. 73′.*

the dermic coat of the follicle, and an internal more transparent layer (*b*, *b*) next the hair. The former corresponds with the deeper and more recent layer of the cuticle in general, and contains blastema, with nuclei, and growing cells, which at the lower part pass continuously into those of the hair-knob; the latter represents the superficial and more mature part of the cuticle, and consists of oblong flattened cells, many of them with nuclei, and lying two or three deep. This innermost layer, when detached,

* Magnified view of the root of a hair (after Kohlräusch). *a*, Stem or shaft of hair cut across. *b*, Inner, and *c*, outer layer of the epidermic lining of the hair follicle, called also the root-sheath. *d*, Dermic or external coat of the hair follicle, shown in part. *e*, Imbricated scales about to form a cortical layer on the surface of the hair.

exhibits impressions of cross lines on its surface, corresponding with those of the imbricated scaly coating of the hair, next which it lies. Between the two layers of the cuticular lining here described is interposed a lamina, having the characters of fenestrated membrane, being transparent and homogeneous, and perforated with round, oval, and irregularly-shaped holes; although some anatomists maintain that the structure in question is merely a layer of somewhat flattened cells, without nuclei, in which perforations are produced by accidental laceration.

Fenestrated membrane.

Attachment of hair to bottom of follicle.

The soft bulbous enlargement of the root of the hair is attached by its base to the bottom of the follicle, and at the circumference of this attached part it is continuous with the epidermic lining; at the bottom of the follicle it, in fact, takes the place of the epidermis, of which it is a growth or extension, and this part of the follicle is the true matrix of the hair, being, in reality, a part of the corium (though sunk below the general surface), which supplies material for the production of the hair. This productive part of the follicle is, accordingly, remarkably vascular; in the large tactile hairs on the snout of the seal and some other animals, it is raised in form of a conical vascular papilla or pulp, which fits into a corresponding excavation of the hair root, and Kölliker states that a similar structure exists in the hairs generally, both small and large, of man as well as quadrupeds. He describes the papilla as being commonly of an ovoid shape and attached to the bottom of the follicle by a narrow base, or a sort of pedicle (figs. 76′ and 77′, *h*). Nervous branches of considerable size enter the follicles of the large tactile hairs referred to, and are probably distributed to the papillæ, though of course not to the epidermic substance of the hairs; the pain occasioned by pulling the hair would seem to suggest that the human hair-follicles are not unprovided with nerves.

Muscles of hair follicles.

Muscular fibres are connected with the hair-follicles. Their mode of attachment is described by Kölliker and Lister to be the following: they arise from the most superficial part of the corium, and pass down obliquely to be inserted into the outside of the follicle immediately below the sebaceous glands. They are placed on the side to which the hair slopes, so that their action in elevating the hair is evident.*

* See Observations on the Muscular Tissue of the Skin by Joseph Lister, M.B.; Microscopical Journal for 1853.

Growth of hair.

Growth of hair.—On the surface of the papilla or vascular matrix, at the bottom of the follicle, blastema is thrown out, in which nucleated cells arise. The cells for the most part lengthen out and unite into the flattened fibres which compose the fibrous part of the hair, and certain of them, previously getting filled with pigment, give rise to the coloured streaks in that tissue; their nuclei, at first, also lengthen in the same manner, but, at last, partly become indistinct. The cells next the circumference expand into the scales which form the imbricated cortical layer (fig. 73′, *e*, *e*). The medulla, where it exists, is formed by the cells nearest the centre; these retain their primitive figure longer than the rest; they become coherent, and their cavities may coalesce together by destruction of their mutually adherent parietes, whilst collections of pigment granules make their appearance in them and around their nuclei, forming an opaque mass, which occupies the axis of the hair.

The epidermic substance of the hair, like the cuticle itself, is quite extravascular, but, like that structure also, it is organised and subject to internal organic changes. Thus, in the progress of its growth, the cells change their figure, and acquire greater consistency. In consequence of their elongation, the hair, bulbous at the commencement, becomes reduced in diameter and cylindrical above. But it cannot be said to what precise distance from the root organic changes may extend. Some have imagined that the hairs are slowly permeated by a fluid, from the root to the point, but this has not been proved. The sudden change of the colour of the hair from dark to grey, which sometimes happens, has never been satisfactorily explained.

Appearance of the hair in the fœtus.

Development of the hair in the fœtus.—According to Valentin, the rudiments of the hairs may be discovered at the end of the third or beginning of the fourth month of intra-uterine life, as little black specks beneath the cuticle. Kölliker states that they at first appear as little pits in the corium (fig. 74′), filled with cells of precisely the same nature as those of the Malpighian or mucous layer of the cuticle, with which they are continuous; so that it might correctly be said, that the hair rudiments are formed of processes of the mucous layer, which sink down into the corium. A homogeneous limiting membrane next appears (fig. 74′, *i*,), inclosing the collection of cells, and continuous above with a similar simple film which at this time lies between the cuticle and the corium. The hair rudiments next lengthen and swell out at the bottom, so as to assume a flask-shape (fig. 75′). Cells are deposited outside the limitary membrane, which are eventually converted into or give place to fibres; and thus the dermic coats

of the follicle are produced. While this is going on outside, the cells within the follicle undergo changes. Those in the middle lengthen out conformably with the axis of the follicle, and give rise

Fig. 74′.*

to the appearance of a short conical miniature hair, faintly distinguishable by difference of shade from the surrounding mass of cells, which are also slightly elongated, but across the direction of the follicle. The papilla (fig. 75′ and 76′, *h*) makes its appearance at the swollen root of the little hair; and the residuary cells contained within the rudimentary follicle form the root sheath, the inner layer of which, lying next to the hair (fig. 76′, *d′*), is soon distinguished by its translucency from the more opaque outer layer that fills up the rest of the cavity. The young hair continuing to grow, at last perforates the cuticle, (fig. 77, *g*), either directly, or after first slanting up for some way between the mucous and horny strata; and Kölliker thinks that, in the former case it may perhaps be aided in its progress by the hard inner layer of the root sheath which appears to make way for it through the cuticle. The young hair is often bent like a whip, and then the doubled part protrudes.

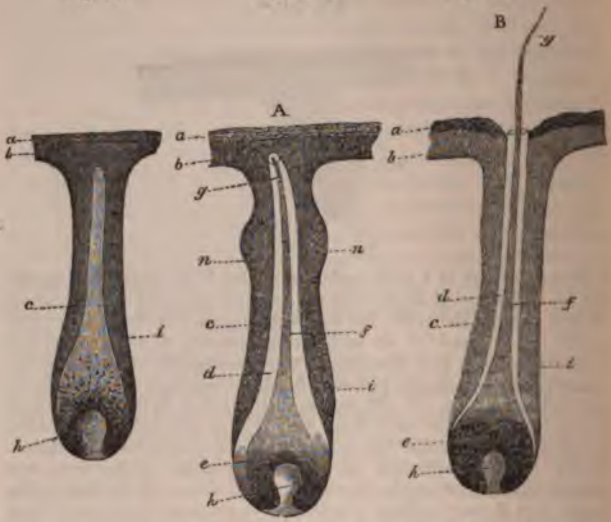
The first hairs produced constitute the *lanugo;* their eruption takes place about the fifth month of intra-uterine life, but many of them are shed before birth, and are found floating in the liquor amnii. Kölliker affirms that the infantile hairs are entirely shed and renewed within a few months after birth; those of the general surface first, and afterwards the hairs of the eyebrows and head, which he finds in process of change in infants about a year old. The new hairs are generated in the follicles of the old. An increased growth of cells takes place in the soft hair-knob, and in the adjoining part of the root sheath (the outer layer); the growing mass protrudes or lengthens out the lower end of the hair follicle, at the bottom of which is found the generative papilla, now, by the interposition of the new cell-growth, withdrawn from the root of the hair. The newly-formed mass of cells, occupying the lower or prolonged part of the follicle, and resting on the papilla, is gradually converted into a new hair with its root sheath, just as in the primitive process of formation in the embryo; and as the new hair lengthens and emerges from the follicle, the old one, detached from its matrix, is

Reproduction of hair after shedding;

* Hair rudiment from an embryo of six weeks, magnified 350 diameters.—*a.* Horny and *b.* mucous or Malpighian layer of cuticle. *i.* Limitary membrane. *m.* Cells, some of which are assuming an oblong figure, which chiefly form the future hair. (After Kölliker.)

gradually pushed towards the opening, and at last falls out, its root sheath having previously undergone partial absorption. When a hair

Fig. 75′.* Fig. 76′.† Fig. 77′.‡



after evulsion.

is pulled out, a new one grows in its place, provided the follicle (from which the growth proceeds) remains entire. Heusinger, who experimentally studied the process in the large hairs situated on the lips of the dog, found that a new hair appeared above the surface in a few days after the evulsion of the old one, and attained its full size in about three weeks.

Arrangement of the hairs.

Distribution and arrangement.—Hairs are found on all parts of the skin except the palms of the hands and soles of the feet, the dorsal surface of the third phalanges of the fingers and toes, the upper eyelids, the glans, and the inner surface of the prepuce. They are for the most part grouped together, and not placed at equal distances.

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* Rudiment of a hair of the eyebrow magnified 50 diameters. The cells form an internal cone indicating the position of the future hair.—*a.* Horny layer of cuticle. *b.* Mucous layer. *c.* External layer of root sheath. *i.* Limitary membrane. *h.* Papilla. (After Kölliker.)

† Hair rudiment measuring 0·22 of a line, from the eyebrow with the young hair not yet risen through the cuticle. *a, b, c, h, i,* as in fig. 75. *e.* Hair-knob. *f.* Stem, and *g,* point of the hair. *d.* Internal layer of the root sheath, still inclosing the hair. *n, n.* Commencing sebaceous follicles. (After Kölliker.)

‡ Hair follicle from the eyebrow with the hair just erupted; the inner layer of the root sheath rises to the mouth of the hair follicle. The letters denote the same parts as in fig. 76′. (After Kölliker.)

Except those of the eyelashes, which are implanted perpendicularly to the surface, they have usually a slanting direction, which is wonderfully constant in the same parts.*

Chemical nature.—The chemical composition of hair has been investigated principally by Vauquelin, Scherer, and Van Laer. When treated with boiling alcohol, and with ether, it yields a certain amount of oily fat consisting of margarin, margaric acid, and olein, which is red or dark coloured, according to the tint of the hair. The animal matter of the hair thus freed from fat, is supposed to consist of a substance yielding gelatin, and a protein compound containing a large proportion of sulphur. It is insoluble in water, unless by long boiling under pressure, by which it is reduced into a viscid mass. It readily and completely dissolves in caustic alkalies. By calcination hair yields from 1 to 1½ per cent. of ashes, which consist of the following ingredients, viz., peroxide of iron, and according to Vauquelin, traces of manganese, silica, chlorides of sodium and potassium, sulphates of lime and magnesia, and phosphate of lime. With the exception of the bones and teeth, no tissue of the body withstands decay after death so long as the hair, and hence it is often found preserved in sepulchres, when nothing else remains but the skeleton. Chemical composition.

Glands of the skin.—These are of two kinds, the sweat glands, and the sebaceous, which yield a fatty secretion.

The sudoriferous glands or *sweat-glands.*—These are seated on the under surface of the corium, and at variable depths in the subcutaneous adipose tissue. They have the appearance of small round reddish bodies, each of which, when examined with the microscope, is found to consist of a fine tube, coiled up into a ball (though sometimes forming an irregular or flattened figure), from which the tube is continued, as the duct of the gland, upwards through the true skin and cuticle, and opens on the surface by a slightly widened orifice. The duct, as it passes through the epidermis, is twisted like a corkscrew, that is, in parts where the epidermis is sufficiently thick to give room for this; lower down it is but slightly curved (fig. 78′). Sometimes the duct is formed of two coiled-up branches, which join at a short distance from the gland, as happens to be the case in the specimen represented in the figure. The tube, both in the gland and where it forms the excretory duct, consists of an outer coat, continuous with the corium, and reaching no higher than the surface of the true skin, and an epithelial lining, continuous with the epidermis, which alone forms the twisted part of the duct. The outer, dermic or fibrous, coat is formed by fine fibres of areolar tissue. Sweat-glands. Sweat-ducts.

* The direction of the hairs in different parts is well seen in the new-born infant. As so observed, it has been described and represented in figures, by Eschericht. Müller's Archiv., 1837.

Kölliker has failed to discover a basement membrane, at least in glands fully developed; on the other hand, he has found that the larger gland-ducts in the axilla, at the root of the penis, on the labia majora, and in the neighbourhood of the anus, contain between their fibrous and epithelial coats a layer of non-striated muscular fibres, arranged longitudinally. He observes also, that in the larger glands the duct is rarely simple, being more usually parted by repeated dichotomous division into several branches, which before ending give off short cæcal processes; in rare cases the branches anastomose. On carefully detaching the cuticle from the true skin, after its connection has been loosened by putrefaction, it usually happens that the cuticular linings of the sweat-ducts get separated from their interior to a certain depth, and are drawn out in form of short threads attached to the under surface of the epidermis. Each little sweat-gland is supplied with a dense cluster of capillary blood-vessels.

Fig. 78′.*

Contents of sweat-glands.

The *contents* of the smaller sweat-glands are fluid, without any formed elements; but in the larger sweat-glands of the axilla the contents are semi-fluid, and abound in fine pale granules and nuclei; or they are extremely viscid with a varying quantity of large, opaque, colourless, or yellow granules, with nuclei and cells, similar to epithelium cells. Kölliker states that from the nature of their contents these larger glands might be separated into a distinct group from the ordinary sweat-glands, were it not for the presence of transitional forms.

Their distribution.

Sweat-glands exist in all regions of the skin, and attempts have been made to determine their relative amount in different parts, for they are not equally abundant everywhere; but while it is easy to count their numbers in a given space on the palm and sole, the numerical proportion assigned to them in most other regions must be taken with considerable allowance. According to Krause, nearly 2800 open on a square inch of the palm of the hand, and somewhat fewer on an equal extent of the sole of the foot. He assigns rather more than half this number to a square inch on the back of the hand, and not quite so many to an equal portion of surface on the forehead, and the front

* Magnified view of a sweat-gland with its duct (after Wagner). *a*. The gland surrounded by vesicles of adipose tissue. *b*. The duct passing through the corium. *c*. Its continuation through the lower, and *d* through the upper part of the epidermis.

and sides of the neck; then come the breast, abdomen, and fore-arm, where he reckons about 1100 to the inch, and lastly, the lower limbs and the back part of the neck and trunk, on which the number in the same space is not more than from 400 to 600.

Size differs.

The size of the sweat-glands also varies. According to the observer last named, the average diameter of the round-shaped ones is about one-sixth of a line; but in some parts they are larger than this, as for example, in the groin, but especially in the axilla. In this last situation Krause found the greater number to measure from one-third of a line to a line, and some nearly two lines in diameter.

Development of sweat-glands.

The *development* of the sweat-glands has been carefully studied by Kölliker. He states that their rudiments, when first discoverable in the embryo, have much the same appearance as those of the hair, and, in like manner, consist of processes of the mucous layer of the epidermis, which pass down and are received into corresponding recesses of the corium. They are formed throughout of cells collected into a solid mass of an elongated-pyriform, or rather club shape, continuous by its small end with the soft layer of the cuticle, and elsewhere surrounded by a homogeneous limiting membrane, which is prolonged above between the corium and cuticle. The subsequent changes consist in the elongation of the rudimentary gland, the formation of a cavity along its axis—at first without an outlet—the prolongation of its canal through the epidermis to open on the surface, and, in the mean time, the coiling-up of the gradually lengthening gland-tube into a compact ball, and the twisting of the excretory duct as it proceeds to the orifice. The original homogeneous membrane of the duct becomes thickened and is continuous with the surface of the corium, whilst an epithelium appears within, consisting of several layers of polygonal or rounded cells. The ceruminous glands in the auditory passage are known to consist of a tube coiled into a rounded or oval ball, like the sweat-glands; and the investigations of Professor Kölliker show such a further correspondence between the two, in structure and mode of development, as to lead him to regard the ceruminous glands as a mere local variety of the sudoriferous, which, as above noticed, present specialities both of structure and secretion in particular regions of the body.

Sebaceous glands.

The *sebaceous glands* pour out their secretion at the roots of the hairs, for, with very few isolated exceptions, they open into the hair follicles, and are found wherever there are hairs. Each has a small duct, which opens at a short distance within the mouth of the hair follicle, and, by its other end, leads to a cluster of small rounded secreting saccules, which, as well as the duct, are lined by epithelium, and usually charged with the fatty secretion, mixed with detached epithelium particles. The number of saccular recesses connected with the duct usually varies from four or five to twenty; it may be reduced to two or three, in very small glands, or even to one, but this is rare. These glands are lodged in the substance of the corium, Several may open into the same hair follicle, surrounding it on all sides, and their size is not regulated by the magnitude of the

hair. Thus, some of the largest are connected with the fine downy hairs on the alæ of the nose and other parts of the face, and there they often become unduly charged with pent-up secretion.*

Development of sebaceous glands.

Development of the sebaceous glands.—According to Professor Kölliker the rudiments of the sebaceous glands sprout like little buds from the sides of the hair follicles, and are at first, in fact, excrescences of the external or mucous layer of the root sheath (fig. 76′, *n*, *n*), and are composed entirely of nucleated cells. Each little process soon assumes a flask shape and is at first solid; but in due time a group of cells containing fat particles appears in its centre, and gradually extends itself along the axis of the pedicle until it penetrates through the root sheath, and the fat cells thus escape into the cavity of the hair follicle, and constitute the first secretion of the sebaceous gland. They are soon succeeded by others of the same kind, and the little gland is established in its office. Additional saccules and recesses, by which the originally simple cavity of the gland is complicated, are formed by budding-out of its epithelium, as the first was produced from the epithelial root sheath, and are excavated in a similar manner.

It would thus appear that the rudiments of the hair follicles, sweat-glands and sebaceous glands, are all derived from the same source. They all originally appear as solid bud-like excrescences of the soft Malpighian or mucous layer of the epidermis, for the outer stratum of the root sheath must be regarded as such; these grow down into the corium, in which recesses are formed to receive them, and which, of course, yields the material required both for the production of new cells for their further growth and for the maintenance of their secreting function.

Uses of the skin.

Functions and vital properties of the skin.—The skin forms a general external tegument to the body, defining the surface, and coming into relation with foreign matters externally, as the mucous membrane, with which it is continuous and in many respects analogous, does internally. It is also a vast emunctory, by which a large amount of fluid is eliminated from the system, in this also resembling certain parts of the mucous membrane. Under certain conditions, moreover, it performs the office of an absorbing surface, but this function is greatly restricted by the epidermis. Throughout its whole extent the skin is endowed with *tactile sensibility*, but in very different degrees in different parts. On the skin of the palm and fingers, which is largely supplied with nerves and furnished with numerous prominent papillæ, the sense attains a high degree of acuteness; and this endowment, together with other conformable arrangements and adaptations, invests the human hand with the character of a special organ of touch. A certain though low degree of vital contractility, depending doubtless on the muscular fibres in its tissue, also belongs to the skin. This shows itself in the

Sensibility.

Contractility.

* A few years ago it was discovered by Dr. Gustavus Simon, that the sebaceous and hair follicles were infested by a worm, which he has described and delineated in Müller's Archiv. for 1842. Since then, further interesting details respecting this curious parasite, with observations on its development, have been contributed by Mr. E. Wilson. Phil. Trans. 1844.

general shrinking of the skin caused by naked exposure to cold and by certain mental emotions, and producing the state of the surface named "cutis anserina," in which the muscular fibres protrude the hair follicles with which they are connected, whilst they retract or depress the intermediate cutaneous tissue; and this condition of the skin may be produced locally by the electric stimulus applied by means of the magneto-electric apparatus. The erection of the nipple is probably also due to contractility. The scrotum, as is well known, becomes obviously shrunk and corrugated by the application of cold or mechanical irritation to its surface; but in this case the contraction takes place in the subcutaneous tissue, and the skin is puckered.

Regeneration.

Reproduction of skin.—When a considerable portion of the skin is lost, the breach is repaired partly by a drawing inwards of the adjoining skin, and partly by the formation of a dense tissue, less vascular than the natural corium, and in which, so far as I know, hairs and glands are not reproduced, so that some deny that the cutaneous tissue is regenerated. Still the new part becomes covered with epidermis, and its substance sufficiently resembles that of the corium to warrant its being considered as cutaneous tissue regenerated in a simple form. I may add, that in small breaches of continuity from cuts inflicted in early life, the uniting part sometimes acquires furrows similar to those of the adjoining surface.

SECRETING GLANDS.

Term "gland."

The term gland has been applied to various objects, differing widely from each other in nature and office, but the organs of which it is proposed to consider generally the structure, in the present chapter, are those devoted to the function of secretion.

Secretion, what.

By secretion is meant a process in an organised body, by which various matters, derived from the solids or fluids of the organism, are collected and discharged at particular parts, in order to be further employed for special purposes in the economy, or to be simply eliminated as redundant material or waste products. Of the former case, the saliva and gastric juice, and of the latter, which by way of distinction is often called "excretion," the urine and sweat may be taken as examples.

Nutritive secretion.

Secretion is very closely allied to nutrition. In the one process, as in the other, materials are selected from the general mass of blood and appropriated by solid textures; but in the function of nutrition or assimilation, the appropriated matter is destined, for a time, to constitute part of the texture or organ, whereas in secretion it is immediately discharged at a free surface. The resemblance is most striking in those cases in which the waste particles of the texture nourished are shed or cast off at its surface, as in

the cuticle and other epithelial tissues. It has thus been common, with physiological writers, to designate the selection and deposition of material which takes place in nutrition by the term "nutritive secretion," whilst the function of which we have here to consider generally the organs, is named simply "secretion," or sometimes, when necessary for the sake of distinction, "excretive secretion."

Source of secreted matter.

In man, and in animals which possess a circulating blood, that fluid is the source whence the constituents of the secretions are proximately derived; and it is further ascertained, that some secreted matters exist ready-formed in the blood, and require only to be *selected* and separated from the general mass, whilst others would seem to be *prepared* from the materials of the blood, by the agency of the secreting organ. Among the secreted substances belonging to the former category, several, such as water, common salt, and albumen, are primary constituents of the blood, but others, as urea, uric acid, and certain salts, are the result of changes, both formative and destructive, which take place in the solid textures and in the blood itself, in the general process of nutrition. Again, as regards those ingredients of the secretions which are prepared or elaborated in the secretory apparatus, it is to be observed, that they may undergo changes in organic form, as well as in chemical composition. Evidence of this is afforded by the solid corpuscles found in many secretions, as well as by the seminal cells and spermatozoa produced in the testicle.

Conditions presented by secreting apparatus.

In the structural adaptations of a secreting apparatus, it is in the first place provided that the blood-vessels approach some free surface from which the secretion is poured out. The vessels, however, do not open upon the secreting surface, for their coats, as well as the tissue covering them, are permeable to liquids; and the most favourable conditions for the discharge of fluid are ensured by the division of the vessels into their finest or capillary branches, and by their arrangement in close order, as near as possible to the surface. In this condition, their coats are reduced to the greatest degree of tenuity and simplicity, and the blood, being divided into minute streams, is extensively and thoroughly brought into contact with the permeable parietes of its containing channels, as well as effectually and, by reason of its slow motion, for a long time exposed to those influences, whether operating from within or without the vessels, which promote transudation.

Such a simple arrangement as that just indicated is sufficient for the separation of certain substances from the general mass of the blood; for the coats of the vessels and tissue superjacent to them are not permeated with equal facility by all its constituents; and in certain cases the elimination of fluid in the animal body is effected without the necessary aid of any more complicated apparatus. Thus, the exhalation of carbonic acid and watery vapour from the interior of the lungs and air passages, is probably produced in this simple manner, although the structure of the exhaling membrane is, for other reasons, complex; and the discharge of fluid into cavities lined by serous membranes, which is known to be preternaturally increased by artificial or morbid obstruction in the veins, may be a case of the same kind. Simplest mode of secretion.

But another element is almost always introduced into the secreting structure, and plays an important part in the secretory process; this is the nucleated cell. A series of these cells, which are usually of a spheroidal or polyhedral figure, is spread over the secreting surface, in form of an epithelium, which rests on a simple membrane, named the basement membrane, or membrana propria. This membrane, itself extravascular, limits and defines the vascular secreting surface; it supports and connects the cells by one of its surfaces, whilst the other is in contact with the blood-vessels, and it may very possibly, also, minister, in a certain degree, to the process of secretion, by allowing some constituents of the blood to pass through it more readily than others. But the cells are the great agents in selecting and preparing the special ingredients of the secretions. They attract and imbibe into their interior those substances which, already existing in the blood, require merely to be segregated from the common store and concentrated in the secretion, and they, in certain cases, convert the matters which they have selected into new chemical compounds, or lead them to assume organic structure. A cell thus charged with its selected or converted contents yields them up to be poured out with the rest of the secretion, the contained substance escaping from it either by exudation or, as is probably more common, by dehiscence of the cell-wall, which, of course, involves the destruction of the cell itself. Cells filled with secreted matter may also be detached and discharged entire with the fluid part of the secretion, and, in all cases, new cells speedily take the place of those which have served their Agency of cells.

connected with the mucous membrane of the intestines, and known by the names of the solitary and the agminated glands, which differ from all those hitherto spoken of, inasmuch as they are small saccules without an opening. Some anatomists are of opinion that they discharge their contents, from time to time, by bursting; whilst others, without denying the possibility of this, are disposed to take a different view of these glandular bodies, and (as, at any rate there are no ducts) refer them to the class of "ductless glands," under which head they will be again adverted to. The full description of these glands, as well as of the peculiarities in the structure of the liver and kidney above referred to, belongs to the details of special anatomy.

Lymphatics and nerves of glands.

Besides blood-vessels, the glands are furnished with lymphatics, but the arrangement of these within the compound glands, though it is most probably reticular, has not been fully traced. Branches of nerves have also been followed, for some way, into these organs, and the well-known fact, that the flow of secretion in several glands is affected by mental emotions, shows that an influence is exerted on secreting organs through the medium of the nerves. It has not been ascertained how the ultimate ramifications of the nerves are disposed of in the glandular structure, nor how they are related to its more immediate constituents.

Substance of glands.

From what has been stated, it will be apparent that the substance of a gland consists of the ducts, blood-vessels, lymphatics and a few nerves, in some cases connected by an intervening tissue. In the testicle there is a very small amount of intermediate areolar tissue, which, with the aid of the blood-vessels, holds the tubules but feebly together, so that the structure is comparatively loose, and readily admits of being teazed out; but then it is sufficiently protected and supported by a fibrous capsule on the outside, and fibrous septa within the gland. In the racemose, or vesicular, glands, there is a good deal of uniting areolar tissue, which surrounds collectively each group of vesicles, binds together the lobules, and supports the vessels in their ramifications. The substance of the kidney contains scarcely any distinctly characterised areolar tissue, except bundles which here and there accompany the larger branches of vessels, but, according to Mr. Bowman, there is more or less of a soft, amorphous granular matter among the tubules and blood-vessels, which bind them together, especially in

the parts of the organ, where they have a straight course. *Parenchyma* is a word sometimes employed in describing the glands, though less in use now than formerly. It has sometimes been employed merely to denote the solid part of a gland composed of all the tissues already mentioned; at other times, it has been used to signify any substance, of whatever nature, lying between the ducts, vessels, and nerves. In this last sense, the parenchyma is, in certain glands, represented by areolar tissue, in others, as the kidney, by amorphous matter, whilst there are some in which it cannot be said to exist. Term "parenchyma."

Some glands have a special envelope, as in the case with the kidney and testicle; others, as the pancreas, have none. Envelope.

The ducts of glands ultimately open into cavities lined by mucous membrane, or upon the surface of the skin. They are sometimes provided with a reservoir, in which the secretion is collected, to be discharged when the purposes of the economy demand. The reservoir of the urine receives the whole of the secreted fluid; in the gall-bladder, on the other hand, only a part of the bile is collected. The vesiculæ seminales afford another example of these appended reservoirs. The ducts are constructed of a basement membrane and lining of epithelium, and in their smaller divisions there is nothing more, but in the larger branches and trunks a fibro-vascular layer is added, as in the ordinary mucous membrane, with which many of them are continuous, and with which they all agree in nature. A more or less firm outer coat, composed of areolar tissue, comes, in many cases, to surround the mucous lining, and between the two, or, at any rate, outside the mucous coat, there are in many ducts muscular fibres of the plain variety, disposed in two layers, in the more internal and more considerable of which layers the fibres run longitudinally, and in the other circularly. The epithelium is usually composed of spheroidal or polyhedral particles at the commencement of the ducts, and is columnar in the rest of their length, though sometimes flattened or scaly, as in the mammary gland. Reservoirs of secretion. Structure of ducts.

DUCTLESS OR VASCULAR GLANDS.

There are certain bodies which have received the name of glands on account of their resemblance in general appearance Definition.

and structure to the ordinary secreting organs. They differ, however, from the latter in the fact of their possessing no ducts for the conveyance of their secretion; so that the products of secretive action, if finding any outlet, are compelled to do so by rupture, by filtration through the tissues, or by re-absorption into the circulating current. The bodies in question have been termed "ductless" for this obvious anatomical reason; and "vascular," on certain physiological or theoretic grounds, as they are supposed to effect some change in the blood which is transmitted through them.

Enumeration. To this class belong the following bodies:—the spleen, the thyroid body, thymus gland, supra-renal capsules, pituitary body; and, according to Kölliker, Huxley, and others, we ought to place in the same category the solitary closed follicles of the stomach and intestines, the Peyerian glands, the follicular glands at the root of the tongue, and the lymphatic glands generally. The peculiar structure of each of these organs (except the lymphatic glands, already treated of) will be considered in its proper place in that portion of this work which is devoted to special anatomy; and we have here to give only a general outline of those structural provisions which are, with more or less modification, common to them all.

General structure. The following may be taken as a general account of the mode in which their constituent elements are arranged. The form of the gland is determined by a fibrous, and in some instances dense and firm, investing membrane, which in the larger organs is furnished with prolongations projecting inwards as septa, giving considerable firmness to the texture, and either forming loculi or rounded cavities within them, or merely leaving spaces between the septa, in which a peculiar parenchyma is placed. Membrane. The investing membrane consists of both white and elastic fibres, in varying proportion, and, in many instances in the lower animals, of non-striated muscular fibres. Each gland is abundantly supplied with blood-vessels, Vessels. both arterial and venous; the former commonly dividing frequently, but entering into no anastomosis until they have arrived at their ultimate ramification in a capillary plexus; the latter (the veins) are usually large, valveless, and in some situations appear dilated into sacs; but this appearance has been questioned. Lymphatic vessels and nerves exist in very varying proportions.

Cells. The blood-vessels as they pass through these glands are in some cases closely surrounded by a peculiar pulpy substance,

varying in amount and colour at different periods, but generally existing in considerable quantity. This pulp consists of cells, nuclei, granular matter, and fat-molecules. The cells are of very different kinds and vary widely in size; some resemble lymph, chyle, or pale blood-corpuscles; others, free nuclei; some are large compound cells, containing globules closely resembling those of the blood in their interior; others contain many nuclei, and much granular matter.

These being the general characters of the ductless glands, the varieties met with in the human body may be arranged as follows:— Varieties.

a. Rounded and closed capsules filled with nucleated cells, nuclei, and intercellular fluid, and traversed by blood-capillaries; the capsules placed singly or in flat patches under a mucous membrane (solitary and agminated intestinal glands), or surrounding a simple or complex recess, lined by and opening on the surface of a mucous membrane (certain lingual and pharyngeal glands, and tonsils); it being uncertain whether the contents of the capsules are discharged by rupture or transudation, or taken up by absorption.

b. A lobulated organ inclosing a sinuous internal cavity, with no outlet, filled with a liquid secretion containing corpuscles; the cavity branching into the lobules, and ending in the smallest of them, according to one opinion, by groups of saccular dilatations of its membrana propria, covered outwardly by capillary blood-vessels, as in the racemose secreting glands. According to another view the walls of the cavity in an ultimate lobule are not set round with saccules, but with small solid pellets, formed of aggregated corpuscles similar to those of the fluid, and bounded towards the outer surface of the lobule by a membrana propria, *within* which is a group of blood-vessels pervading the corpuscular matter, as in *a* (thymus).

c. A glandular body containing different-sized locular spaces formed by a stroma of fibrous or more or less homogeneous connective tissue: the loculi containing granules, nuclei, and nucleated cells of various sizes, with intercellular fluid (anterior lobe of the pituitary body and supra-renal capsules), or lined by a membrana propria and epithelium, and filled with clear tenacious fluid (thyroid body).

d. An organ containing a peculiar pulp lodged in the interstices of a trabecular and highly vascular structure; also

capsules with contents as in *a*, attached to the vessels, and surrounded by the pulp, which, while containing collections of red blood-corpuscles in various conditions, resembles generally in nature the matter within the capsules, and is likewise traversed by fine blood-vessels (spleen).

e. Rounded or oval bodies having in their interior intercommunicating loculi traversed by blood-capillaries, and filled with a delicate spongy tissue, the areoles of which communicate with entering and issuing lymphatic or lacteal vessels, and are filled with cells and nuclei identical with those of the lymph and chyle (lymphatic glands).

Function. The purposes fulfilled by these organs are still involved in great obscurity; and very different opinions are held on the subject by eminent authorities in Physiology.

ELEMENTS OF ANATOMY.

INTRODUCTION.

THE material objects which exist in nature belong to two great divisions; those which are living or which have lived, and those which neither are nor have ever been endowed with life. The first division comprehends animals and plants, the other mineral substances. **Division of natural bodies.**

In a living animal or plant, changes take place and processes are carried on, which are necessary for the maintenance of its living state, or for the fulfilment of the ends of its being; these are termed its functions, and certain of these functions being common to all living beings serve among other characters to distinguish them from inert or mineral substances. Such are the function of *nutrition*, by which living beings take extraneous matter into their bodies and convert it into their own substance, and the function of generation or *reproduction*, by which they give rise to new individuals of the same kind, and thus provide for the continuance of their species after their own limited existence shall have ceased.

But in order that such processes may be carried on, the body of a living being is constructed with a view to their accomplishment, and its several parts are adapted to the performance of determinate offices. Such a constitution of body is termed organisation, and those natural objects which possess it are named *organised bodies*. Animals and plants, being so constituted, are organised bodies, while minerals, not possessing such a structure, are *inorganic*.

The object of anatomy, in its most extended sense, is to ascertain and make known the structure of organised bodies. But the science is divided according to its subjects; the **Object of Anatomy.**

investigation of the structure of plants forms a distinct study under the name of Vegetable Anatomy, and the anatomy of the lower animals is distinguished from that of man or human anatomy under the name of Comparative Anatomy.

Organs and textures.

On examining the structure of an organised body, we find that it is made up of members or organs, through means of which its functions are executed, such as the root, stem, and leaves of a plant, and the heart, brain, stomach, or limbs of an animal; and further, that these organs are themselves made up of certain constituent materials named tissues or textures, as the cellular, woody, and vascular tissues of the vegetable, or the osseous, muscular, areolar, vascular, and various others, which form the animal organs.

Most of the textures occur in more than one organ, and some of them indeed, as the areolar and vascular, in nearly all, so that a multitude of organs, and these greatly diversified, are constructed out of a small number of constituent tissues, just as many different words are formed by the varied combinations of a few letters; and parts of the body, differing widely in form, construction, and uses, may agree in the nature of their component materials. Again, as the same texture possesses the same essential characters in whatever organ or region it is found, it is obvious that the structure and properties of each tissue may be made the subject of investigation apart from the organs into whose formation it enters.

General and Descriptive Anatomy.

These considerations naturally point out to the Anatomist a twofold line of study, and have led to the subdivision of Anatomy into two branches, the one of which treats of the nature and general properties of the component textures of the body; the other treats of its several organs, members, and regions, describing the outward form and internal structure of the parts, their relative situation and mutual connection, and the successive conditions which they present in the progress of their formation or development. The former is usually named "General" Anatomy, the latter "Special" or "Descriptive" Anatomy.*

* These names have been objected to, and the terms Histology (ἱστὸς, a web, and λόγος, a discourse), and Morphology (μορφὴ, form, &c.), themselves not free from objection, have been proposed in their stead; there seems no sufficient reason for the substitution; the latter term, indeed, is often used in a different sense; the former is now, however, gaining acceptance, both in this country and elsewhere.

GENERAL ANATOMY.

GENERAL CONSIDERATIONS ON THE TEXTURES.

Enumeration of the textures.

THE human body consists of solids and fluids. Only the solid parts can be reckoned as textures, properly so called; still, as some of the fluids, viz. the blood, chyle, and lymph, contain in suspension solid organised corpuscles of determinate form and organic properties, and are not mere products or secretions of a particular organ, or confined to a particular part, the corpuscles of these fluids, though not coherent textures, are to be looked upon as organised constituents of the body, and as such may not improperly be considered along with the solid tissues. In conformity with this view the textures and other organised constituents of the frame may be enumerated as follows :—

The blood, chyle, and lymph.
Epidermic tissue, including epithelium, cuticle, nails, and hairs.
Pigment.
Adipose tissue.
Areolar or connective tissue.
Fibrous tissue.
Elastic tissue.
Cartilage and its varieties.
Bone or osseous tissue.
Muscular tissue.
Nervous tissue.
Blood-vessels.
Absorbent vessels and glands.
Serous and synovial membranes.

b 2

Mucous membranes.
Skin.
Secreting glands.
Vascular or ductless glands.

Organic systems.

Every texture taken as a whole was viewed by Bichat as constituting a peculiar system, presenting throughout its whole extent in the body characters either the same, or modified only so far as its local connections and uses rendered necessary; he accordingly used the term "organic systems" to designate the textures taken in this point of view, and the term has been very generally employed by succeeding writers. Of the tissues or organic systems enumerated, some are found in nearly every organ; such is the case with the areolar or connective tissue, which serves as a connecting material to unite together the other tissues which go to form an organ; the vessels, which convey fluids for the nutrition of the other textures, and the nerves, which establish a mutual dependence among different organs, imparting to them sensibility, and governing their movements. These were named by Bichat the "general systems." Others again, as the cartilaginous and osseous, being confined to a limited number, or to a particular class of organs, he named "particular systems." Lastly, there are some tissues of such limited occurrence that it has appeared more convenient to leave them out of the general enumeration altogether, and to defer the consideration of them until the particular organs in which they are found come to be treated of. Accordingly the tissues peculiar to the crystalline lens, the enamel of the teeth, and some other parts, though equally independent textures with those above enumerated, are for the reason assigned not to be described in this part of the work.

General and particular or local systems.

It is further to be observed, that the tissues above enumerated are by no means to be regarded as simple structural elements; on the contrary, many of them are complex in constitution, being made up of several more simple tissues. The blood-vessels, for instance, are composed of several coats of different structure, and some of these coats consist of more than one tissue. They are, strictly speaking, rather organs than textures; and indeed it may be remarked, that the distinction between textures and organs has not in general been strictly attended to by anatomists. The same remark applies to mucous membrane and the tissue of the glands, which structures, as commonly understood, are

highly complex. Were we to separate every tissue into the simplest parts which possessed assignable form, we should resolve the whole into a very few constructive elements; and, having regard to form merely, and not to difference of chemical constitution, we might reduce these elements to the following, viz. 1. *simple fibre*, 2. *homogeneous membrane*, either spread out or forming the walls of tubes or *cells*, and 3. *globules* or *granules*, varying in diameter from the $\frac{1}{12000}$th to the $\frac{1}{6000}$th of an inch. These, with a quantity of *amorphous matter*, homogeneous or molecular, might be said, by their varied combinations, to make up the different kinds of structure which we recognise in the tissues; and if we take into account that the chemical nature of these formative elements and of the amorphous matter may vary, it will be readily conceived that extremely diversified combinations may be produced. Elements of structure.

PHYSICAL PROPERTIES.

The animal tissues like other forms of matter are endowed with various physical properties, such as consistency, density, colour, and the like. Of these the most interesting to the Physiologist is the property of imbibing fluids, and of permitting fluids to pass through their substance, which is essentially connected with some of the most important phenomena that occur in the living body, and seems indeed to be indispensable for the maintenance and manifestation of life.

All the soft tissues contain water, some of them more than four-fifths of their weight; this they lose by drying, and with it their softness and flexibility, shrinking up into smaller bulk and becoming hard, brittle, and transparent; but when the dried tissue is placed in contact with water, it greedily imbibes the fluid again, and recovers its former size, weight, and mechanical properties. The imbibed water is no doubt partly contained mechanically in the interstices of the tissue, and retained there by capillary attraction, like water in moist sandstone or other inorganic porous substances; but it has been questioned whether the essential part of the process of imbibition by an animal tissue is to be ascribed to mere porosity, for the fluid is not merely lodged between the fibres or laminæ, or in the cavities of the texture; a part, probably the chief part, is incorporated with the matter which forms the tissue, and is in a state of union with it, which is supposed to be more intimate than could well be ascribed to the mere inclusion of a fluid in the pores of another substance. Be this as it may, it is clear that the tissues, even in their inmost substance, are permeable to fluids, and this property is indeed necessary, not only to maintain their due soft-

ness, pliancy, elasticity, and other mechanical qualities, but also to allow matters to be conveyed into and out of their substance in the process of nutrition.*

CHEMICAL COMPOSITION.

Ultimate chemical constituents.

THE human body is capable of being resolved by ultimate analysis into chemical elements, or simple constituents, not differing in nature from those which compose mineral substances. Of the chemical elements known to exist in nature, the following have been discovered in the human body, though it must be remarked, that those at the bottom of the list occur only in exceedingly minute quantity; oxygen, hydrogen, carbon, nitrogen, phosphorus, sulphur, chlorine, fluorine, potassium, sodium, calcium, magnesium, iron, silicon, manganese, aluminum, copper.

Proximate constituents.

These ultimate elements do not directly form the textures or fluids of the body; they first combine to form certain compounds, and these appear as the more immediate constituents of the animal substance; at least the animal tissue or fluid yields these compounds, and they in their turn are decomposed into the ultimate elements. Of the immediate constituents some are found also in the mineral kingdom, as for example, water, chloride of sodium or common salt, and carbonate of lime; others, such as albumen, fibrin, and fat, are peculiar to organic bodies, and are accordingly named the proximate organic principles.

Their general characters.

The animal proximate principles have the following leading characters: They all contain carbon, oxygen, and hydrogen, and the greater number also nitrogen; they are all decomposed by a red heat; and, excepting the fatty and acid principles, they are, for the most part, extremely prone to putrefaction, or spontaneous decomposition, at least, when in a moist state; the chief products to which their putrefaction gives rise being water, carbonic acid, ammonia, and sulphuretted, phosphuretted, and carburetted hydrogen gases. The immediate compounds found in the solids and fluids of the human body are the following:

Enumeration.

I. *Azotised substances*, or such as contain nitrogen, viz.

* The consideration of the phenomena connected with the transmission of liquids and gases through the animal tissues, though highly important, does not strictly belong to an anatomical work. Mr. Graham's Chemistry, page 76, and his Memoir on "Osmose," Phil. Trans. 1854, may be consulted as original sources of information on this subject.

albumen, fibrin, casein, gelatin, chondrin, extractive soluble in alcohol, extractive soluble in water, salivin, kreatin, pepsin, globulin, mucus, horny matter or keratin, pigment, hæmatin, pyin, urea, uric acid, hippuric acid, leucin, tyrosin, azotised biliary compounds.

II. *Substances destitute of nitrogen*, viz. fatty matters, (except cerebric acid,) sugar of milk, animal glucose, inosit, lactic acid, certain principles of the bile.

Some of the substances now enumerated require no further notice in a work devoted to anatomy. Of the rest, the greater number will be explained, as far as may be necessary for our purpose, in treating of the particular solids or fluids in which they are chiefly found; but there are a few of more general occurrence, the leading characters of which it will be advisable here to state very briefly, viz. :—

A. *Albuminoid principles*, albumen, fibrin, and casein. Coagulable—fibrin spontaneously, albumen by heat, casein by rennet. Precipitated by mineral acids, tannic acid, alcohol, corrosive sublimate, subacetate of lead, and several other metallic salts. *When coagulated*, not soluble in water, cold or hot, unless after being altered by long boiling; insoluble in alcohol; soluble in alkalies; soluble in very dilute and also in concentrated acids; the solutions precipitated by red and yellow prussiates of potash.

B. *Gelatinous principles*, gelatin and chondrin. Not dissolved by cold water; easily soluble in hot water; the solution gelatinising when cold. Precipitated by tannic acid, alcohol, ether, and corrosive sublimate, and not by the prussiates of potash. *Chondrin*, precipitated by acids, alum, sulphate of alumina, persulphate of iron, and acetate of lead, which do not precipitate gelatin.

C. *Extractive matters*, associated with lactic acid and lactates. All soluble in water, both cold and hot; some in water only, some in water and rectified spirit; some in water, rectified spirit, and pure alcohol.

D. *Fatty matters.* Not soluble in water, cold or hot; soluble in ether and in hot alcohol.

VITAL PROPERTIES OF THE TEXTURES.

Of the phenomena exhibited by living bodies, there are many which, in the present state of knowledge, cannot be referred to the operation of any of the forces which manifest themselves in inorganic nature; they are therefore ascribed to certain powers, endowments, or properties, which so far

Vital properties and vital stimuli.

as known, are peculiar to living bodies, and are accordingly named "vital properties." These vital properties are called into play by various stimuli, external and internal, physical, chemical, and mental; and the assemblage of actions thence resulting has been designated by the term "life." The words "life" and "vitality" are often also employed to signify a single principle, force, or agent, which has been regarded as the common source of all vital properties, and the common cause of all vital actions.

Assimilative property.

1. Of the vital properties, there is one which is universal in its existence among organised beings, namely, the property, with which all such beings are endowed, of converting into their own substance, or "assimilating," alimentary matter. The operation of this power is seen in the continual renovation of the materials of the body by nutrition, and in the increase and extension of the organised substance, which necessarily takes place in growth and reproduction; it manifests itself, moreover, in individual textures as well as in the entire organism. It has been called the "assimilative force or property," "organising force," "plastic force," and is known also by various other names. But in reality the process of assimilation produces two different effects on the matter assimilated: first, the nutrient material, previously in a liquid or amorphous condition, acquires determinate form; and secondly, it may, and commonly does, undergo more or less change in its chemical qualities. Such being the case, it seems reasonable, in the mean time, to refer these two changes to the operation of two distinct agencies, and, with Schwann, to reserve the name of "plastic" force for that which gives to matter a definite organic form; the other, which he proposes to call "metabolic," being already generally named "vital affinity." Respecting the last-named agency, however, it has been long since remarked, that although the products of chemical changes in living bodies for the most part differ from those appearing in the inorganic world, the difference is nevertheless to be ascribed, not to a peculiar or exclusively vital affinity different from ordinary chemical affinity, but to common chemical affinity operating in circumstances or conditions which present themselves in living bodies only.

Plastic and metabolic forces.

Vital contractility.

2. When a muscle, or a tissue containing muscular fibres, is exposed in an animal during life, or soon after death, and scratched with the point of a knife, it contracts or shortens itself; and the property of thus visibly contracting on the

application of a stimulus is named "vital contractility," or "irritability," in the restricted sense of this latter term. The property in question may be called into play by various other stimuli besides that of mechanical irritation—especially by electricity, the sudden application of heat or cold, salt, and various other chemical agents of an acrid character, and, in a large class of muscles, by the exercise of the will, or by involuntary mental stimuli. The stimulus may be applied either directly to the muscle, or to the nerves entering it, which then communicate the effect to the muscular fibre, and it is in the latter mode that the voluntary or other mental stimuli are transmitted to muscles from the brain. Moreover, a muscle may be excited to contract by irritation of a nerve not directly connected with it. The stimulus, in this case, is first conducted by the nerve irritated, to the brain or spinal cord; it is then, without participation of the will, and even without consciousness, transferred to another nerve, by which it is conveyed to the muscle, and thus at length excites muscular contraction. The property of nerves by which they convey stimuli to muscles, whether directly, as in the case of muscular nerves, or circuitously, as in the case last instanced, is named the "vis nervosa."

How excited.

"Vis nervosa."

Tests of vital contractility.

The evidence that a tissue possesses vital contractility is derived, of course, from the fact of its contracting on the application of a stimulus. Mechanical irritation, as scratching with a sharp point, or slightly pinching with the forceps, electricity obtained from a piece of copper and a piece of zinc, or from a larger apparatus if necessary, and the sudden application of cold, are the stimuli most commonly applied. Heat, when of certain intensity, is apt to cause permanent shrinking of the tissue, or "crispation," as it has been called, which, though quite different in nature from vital contraction, might yet be mistaken for it; and the same may happen with acids and some other chemical agents, when employed in a concentrated state: in using such stimulants, therefore, care should be taken to avoid this source of deception.

Sensibility.

3. We become conscious of impressions made on various parts of the body, both external and internal, by the faculty of sensation; and the parts or textures, impressions on which are felt, are said to be sensible, or to possess the vital property of "sensibility."

This property manifests itself in very different degrees in different parts; from the hairs and nails, which indeed are

Primordial Utricle of Mohl.

only by an inter-cellular substance, which, according to Hugo von Mohl,* has so great a similarity to the substance of the cell-walls that it is impossible, even with the aid of chemical re-agents, to discover a line of demarcation between them. That eminent phytologist supposes that within what is commonly called the cell-wall there exists an extremely delicate membrane, constituting an interior vesicle, which he names the "Primordial utricle." This is in most cases so closely applied to the exterior wall as to be undistinguishable; but in young cells, and in those of strictly cellular plants, such as the Algæ, &c., during the whole of their existence, it may be separated by treating the tissue with alcohol, or hydrochloric or nitric acid, and then the interior vesicle appears shrivelled up and separated from the wall of the cavity. If this view be correct, the cells, as usually recognised, might be regarded as lacunæ in the inter-cellular substance, and the inclosed primordial utricles as the real cells. But the reality of the alleged primordial utricle has recently been called in question, and the supposed internal membrane is held to be merely the limiting surface of the cell-contents shrunk away from the inside of the containing cavity, and perhaps somewhat consolidated and defined by the re-agents employed. Still, whether the cell-contents have a vesicular limiting membrane or not, they originally present a marked contrast in chemical nature to the containing cell-wall and inter-cellular substance, and would appear to fulfil a different purpose in the process of tissue-development.†

Besides such cells, phænogamous or flowering plants contain tubes, vessels, and other forms of tissue (fig. 2′,[4 6]); but a great many plants of the class cryptogamia are composed entirely of cells, variously modified, it is true, to suit their several destinations, but fundamentally the same throughout: nay, there are certain very simple modes of vegetable existence, in which a single cell may constitute an entire plant, as in the well-known green powdery crust which coats over the trunks of trees, damp walls, and other moist surfaces. In this last case, a simple detached cell exercises the functions of an entire independent organism, imbibing and elaborating extraneous matter, extending

* Die vegetabilische Zelle; or English translation by Prof. Henfrey.

† See an interesting discussion of this subject by Mr. Huxley in the British and Foreign Medical Review for 1853.

itself by the process of growth, and continuing its species by generating other cells of the same kind. Even in the aggregated state in which the cells exist in vegetables of a higher order, each cell still, to a certain extent, exercises its functions as a distinct individual; but it is now subject to conditions arising from its connection with the other parts of the plant to which it belongs, and is made to act in harmony with the other cells with which it is associated, in ministering to the necessities of the greater organism of which they are joint members. These elementary parts are therefore not simply congregated into a mass, but combined to produce a regularly organised structure; just as men in an army are not gathered promiscuously, as in a mere crowd, but are regularly combined for a joint object, and made to work in concert for the attainment of it; living and acting as individuals, but subject to mutual and general control.

Now the varied forms of tissue found in the higher orders of plants do not exist in them from the beginning; they are derived from cells. The embryo plant, like the embryo animal, is in its early stages entirely formed of cells, and these of a very simple and uniform character; and it is by a transformation of some of these cells in the further progress of development that the other tissues, as well as the several varieties of cellular tissue itself, are produced. The principal modes, as far as yet known, in which vegetable cells are changed, are the following. **Transformation of vegetable cells.**

1. The cells may increase in size; simply, or along with some of the other changes to be immediately described. **Enlargement.**

2. They alter in shape. Cells have originally a spheroidal or rounded figure; and when in the progress of growth they increase equally, or nearly so, in every direction, and meet with no obstacle, they retain their rounded form. When they meet with other cells extending themselves in like manner, they acquire a polyhedral figure (fig. 2′, [1 2]) by mutual pressure of their sides. When the growth takes place more in one direction than in another, they become flattened, or they elongate and acquire a prismatic, fusiform, or tubular shape (fig. 2′, [3 4 5]). Sometimes, as in the common rush, they assume a starlike figure, sending out radiating branches, which meet the points of similar rays from adjacent cells (fig. 3′.) **Change of figure.**

3. The cells coalesce with adjoining cells, and open into them. In this way a series of elongated cells placed end to **Coalescence with each other.**

end may open into one another by absorption of their cohering membranes, and give rise to a tubular vessel.

Fig. 2′.*

Alteration of substance, and contents.

4. Changes take place in the substance and in the contents of the cells. These changes may be chemical, as in the conversion of starch into gum, sugar, and jelly, and in the production of various coloured matters, essential oils, and the like. Or they may affect the form and arrangement of the contained substances; thus, the contents of the cell very frequently assume the form of granules, or spherules, of various sizes; at other times the contained matter, suffering at the same time a change in its chemical nature and in consistency, is deposited on the inner surface of the cell-wall, so as to thicken and strengthen it. Such "secondary deposits," as they are termed by botanists, usually occur in successive strata, and the deposition may go on till the cavity of the cell is nearly or completely filled up (fig. 4′). It is in this way that the woody fibre and other hard tissues of the plant are formed. It further appears that the particles of each layer are disposed in lines, running spirally round the cell. In place of forming a continuous layer, these secondary deposits may leave little

Fig. 3.′†

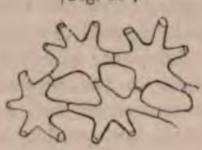


Fig. 4′.‡

* Textures seen in a longitudinal section of the leaf-stalk of a flowering plant.

† Stellate vegetable cells.

‡ Cross section of ligneous cells containing stratified deposit.

spots of the cell-wall uncovered, or less thickly covered, and thus give rise to what is named pitted tissue (fig. 2′,[6]); or they may assume the form of a slender fibre or band, single, double, or multiple, running in a spiral manner along the inside of the cavity, or forming a series of separate rings or hoops, as in spiral and annular vessels (fig. 2′,[7]). New matter may be absorbed or imbibed into the cells; or a portion of their altered and elaborated contents may escape as a secretion, either by transudation through the cell-wall, or by rupture or absorption of the membrane. Lastly, in certain circumstances, cells may be wholly or partially removed by absorption of their substance.

Production of new cells.

5. Cells may produce or generate new cells. The mode in which this takes place will be immediately considered, in speaking of the origin of animal cells.

FORMATION OF THE ANIMAL TEXTURES.

Resemblance of the process in animals and vegetables.

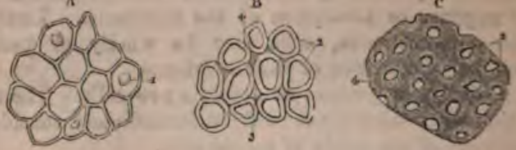
Passing now to the development of the animal tissues, it may first be remarked generally, that in some instances the process exhibits an obvious analogy with that which takes place in vegetables; certain of the animal tissues, in their earlier conditions, appearing in form of a congeries of cells, almost entirely resembling the vegetable cells, and, in their subsequent transformations, passing through a series of changes in many respects parallel to some of those which occur in the progress of vegetable development. Cartilage affords a good example of this. Figures 5′ and 6′, A, are magnified representations of cartilage in its early condition; and whoever compares them with the appearance of vegetable cells, shown in figures 1′ and 2′, must at once be struck with the resemblance. Fig. 6′, B and C, shows the subsequent changes on the primary cells of cartilage; the parietes are seen to have become thickened by deposit of fresh

Fig. 5′.*

* Section of a branchial cartilage of a Tadpole, showing the early condition of the cells; magnified 450 diameters (Schwann).

material, the spaces within the cells are consequently diminished, while the mass between the cavities is increased. Now this change seen to occur in the cartilage cells, though there may be a question as to the precise mode in which it is brought about, may very fairly be compared with the thickening of the sides of the vegetable cells, which takes

Fig. 6'.*



place when they are converted into the woody and other hard tissues. Again, in most cartilages the cells increase in number as they diminish in size, new ones being formed within the old, as happens in many vegetable structures.†

The instance now given, and others to the same effect, which will be mentioned as we proceed, tend to show the fundamental resemblance of the process of textural development in the two kingdoms; but, when we come to inquire into the various modifications which that process exhibits in the formation of particular textures, we encounter serious difficulties. The phenomena are sometimes difficult to observe, and, when recognised, they are perhaps susceptible of more than one interpretation; hence have arisen conflicting statements of fact, and differences of opinion, at present irreconcileable, which future inquiry alone can rectify, and which in the mean time offer serious obstacles to an attempt at generalisation. In what follows, nothing more is intended than to bring together, under a few heads, the more general facts as yet made known respecting the formation of the animal textures, in so far as this may be done without too much anticipating details, which can only

* Cartilage of the branchial ray of a fish (*Cyprinus erythrophthalmus*) in different stages of advancement; magnified 450 diameters (Schwann).

† Remak and Leidy affirm that the corpuscle of cartilage corresponds with the primordial utricle of vegetable tissues; the chondrin-substance being homologous with the vegetable cell-wall and intercellular tissue. This view is adopted by Mr. Huxley, in the paper to which reference has already been made.

body is thicker anteriorly than posteriorly; and the transverse process (parapophysis) thick, and rounded, is obviously continued into the body.

B. THE FIXED VERTEBRÆ.

Fixed vertebræ enter into sacrum and coccyx.

Some of the vertebræ at the lower part of the column lose by their union into a single mass (the sacrum) that character of mobility, from which the term vertebra is derived; and others, (the coccygeal,) dwindled to mere tubercles, the representatives of the bodies of the other segments, have few of those important uses which the complete vertebræ serve.

THE SACRUM.—OS SACRUM.

Sacrum. Situation.

The sacrum, (fig. 10), much the largest piece of the vertebral column, is placed, when the body is in the erect position, at the superior and posterior part of the pelvis, beneath the last lumbar vertebra, but above the coccyx; and between the ossa innominata, where it is inserted, in some measure, like a keystone into an arch.

Fig. 10.*

Direction.

The sacrum is placed very obliquely. It projects backwards from the upper margin, receding to give capacity to the pelvis; and it therefore forms, with the body of the last lumbar vertebra, a projection named the sacro-vertebral angle or promontory. Its figure is triangular in its general outline,—the base being upwards; it is concave anteriorly, and convex posteriorly. We shall consider successively its surfaces, borders, and extremities.

Sacro-vertebral angle. Form.

Anterior surface; its ridges,

The anterior or pelvic surface, which is here shown, is concave from above downwards, slightly so from side to side, and marked by four transverse lines,[1] indicating its original

* A front view of the sacrum:—1, 1. Ridges indicating the place of separation between the sacral vertebræ. 2. Anterior sacral foramina. 3, 4. Lateral surface. 5. A notch which contributes to form a foramen for the passage of the fifth sacral nerve. 6. Surface for connection with the body of the last lumbar vertebra. 7. Articular process on each side. 8. Surface for connection with the coccyx.

foramina, and grooves. division into five pieces. Laterally it presents four foramina[2] (anterior sacral,) for the transmission of the anterior branches of the sacral nerves; these are directed outwards into grooves which lead from the holes, and diminish gradually in size from above downwards; external to the foramina the surface gives attachment to the pyramidalis muscle.

Posterior surface; its spines, groove, cornua, tubercles (two sets), foramina.

The posterior or spinal surface is narrower than the anterior, for the bone is somewhat wedge-shaped from before backwards as well as from above down. This surface is convex, and presents along the median line four small eminences, usually connected so as to form a ridge, which are rudiments of the spinous processes; and beneath them is a triangular groove, or rather an opening, marking the termination of the sacral canal. The margins of the opening are tuberculated, and give attachment to the ligament that closes the canal; the inferior pair of those tubercles (sacral cornua) articulate with the horns of the coccyx. At each side of the median line are two rows of eminences; one row corresponds with the lumbar articular "tubercles," the other ranges with the transverse processes (parapophyses) of the same vertebræ. Between these are the four posterior sacral foramina, which are much smaller than the anterior, and transmit the posterior branches of the sacral nerves.

Inter-vertebral foramina.

Each pair of foramina (anterior and posterior) lead from a single canal within the bone; and this canal, with its apertures, corresponds with the inter-vertebral foramen in other parts of the column.

Lateral surface has two parts; the upper has an auricular surface; the lower is thin.

The borders, or lateral surfaces of the sacrum, present two distinct parts,—one superior, the other inferior. The superior (iliac) is large and irregular;[3] in front, in the fresh state, it is covered with cartilage, and articulated with the ilium; whilst behind is a rough and irregular surface for the attachment of strong ligaments: the anterior smoother part is often named "the *auricular surface.*" The inferior part of the lateral surface,[4] is thin and sinuous, and gives attachment to the sacro-sciatic ligaments. A small indentation[5] terminates this border, which, with the corresponding part of the coccyx, forms a notch for the transmission of the fifth sacral nerve.

Base has the parts of a vertebra.

The *base* or superior extremity, broad, and expanded, resembles the upper surface of the fifth lumbar vertebra. Thus towards the middle it presents an oval surface,[6] cut off obliquely, which articulates with the likewise oblique

body of the last lumbar vertebra; behind this a triangular aperture marking the orifice of the sacral canal; on each side a smooth convex surface, inclined forwards, and continuous with the iliac fossa; an articular process,[7] concave from side to side, which looks backwards and inwards, and receives the inferior articular process of the last lumbar vertebra. Before each articular process is a groove, forming part of the last lumbar inter-vertebral foramen; and behind it is a curved, sharp, and depressed border which bounds the sacral canal, and therefore corresponds with the arches of the vertebræ.

The *apex*, or inferior extremity,[8] directed downwards and forwards, presents an oval convex surface, which articulates with the coccyx. Apex joins the coccyx.

The sacrum in its interior contains much loose spongy substance, and its exterior layer is but moderately compact. Texture. Its central part is also hollowed into a canal (sacral), which curves from above downwards as the bone does; this is of a triangular form, and gradually narrows as it descends. The canal ends in the large aperture on the posterior surface of the bone between the sacral cornua. Sacral canal.

Articulations.—The sacrum articulates with the last lumbar vertebra, the two iliac bones, and the coccyx. Articulations.

PECULIARITIES OF THE SACRUM.

The peculiarities of the sacrum are very numerous. 1. In some cases this bone consists of six instead of five pieces, and it has been found—but much more rarely—reduced to four.* Peculiarities in the number,

2. Occasionally the bodies of the first and second sacral vertebræ are not joined, although complete union has taken place in every other part. and union of the pieces.

3. The lower end of the sacral canal may be open for some extent, in consequence of the vertebral arches not having grown together.

4. In no respect does the sacrum vary more in different skeletons than in the degree of its curve. It is difficult to submit the peculiarities in this respect to a precise and sufficiently comprehensive arrangement; still, after examining a considerable number of skeletons, the majority The curve: its differences;

* Sœmmerring "Lehre von den Knochen und Bändern, &c.," herausgegeben von Rudolph Wagner.—1839.

appeared to admit of being grouped into three sets, as follows :—

classification of them.

a. In one series the anterior surface was comparatively straight, and the slight bend which existed was situate near the lower end.

b. Another group contrasted strongly with the preceding, —the bone being much curved in its whole length, but especially about its middle.

c. A considerable number may be described as holding an intermediate place between the two foregoing classes. The degree of curve was moderate, and chiefly affected the lower third of the bone.

Difference in the male and female.

Difference in the sexes.—Besides possessing the ordinary distinctive character of all parts of the skeleton,—viz. more regularity and smoothness of surface,—the sacrum of the female body is, proportionally to the size of the pelvis or of the skeleton, broader than that of the male.

The curve not characteristic of the sex.

The degree in which the bone is bent has been said by anatomical writers to distinguish between the sexes; but, on comparing their statements, it will be found that they are contradictory—some assigning the greater curve to the female, others, on the contrary, to the male. The measurement of a considerable number of those bones taken from both sexes, has shown me that the curvature cannot be relied on as a distinctive character. The general remarks made in the preceding paragraphs on the varieties presented by the sacrum, with reference to the point in question, are applicable either to the female or the male taken singly, with only this reservation, that those bones which are most curved, and which constitute the second series in the classification there ventured on, commonly belong to the male body.

Sacro-vertebral angle large in female?

It is said by many good observers, that the sacrum usually inclines backwards, from the direction of the lumbar vertebræ, to a greater extent in the skeleton of the female than in that of the male,—thus retiring more from the cavity of the pelvis, and forming a more prominent sacro-vertebral angle.*

* This observation is stated by Blumenbach ("Geschichte und Beschreibung der Knochen," S. 314,) to have been first made by Bonaccioli, a Professor at Ferrara, in the fifteenth century.

THE COCCYX.—OSSA COCCYGIS.

Coccyx, why named.

These bones, when united together, which is usually the case in advanced life, are supposed to resemble a cuckoo's bill, and are therefore called coccygeal (κοκκυξ, a cuckoo). Most commonly there are four of them, sometimes but three; in a few instances five have been found. They diminish gradually in size from above downwards, so that they have, when taken together, a pyramidal form. As they are placed in a continuous line with the inferior third of the sacrum, they form a slightly concave surface anteriorly, and a convex one posteriorly.

Four pieces generally.

Their size.

Fig. 11.*

Characters of first most numerous,

The first of these bones[1] resembles, in some measure, the last vertebra of the sacrum. Its body is small and concave at its upper aspect,[b] which articulates with the extremity of the sacrum; posteriorly, two small processes, termed cornua,[a] project, and rest upon the sacral cornua. The margins (shoulders, as these parts have been named,) of the first piece project outwards, and joining, in some cases, with the sacrum, construct the fifth sacral foramen—as exemplified in fig. 16, B.

the rest have only bodies.

The second bone of the coccyx is somewhat square; the third oblong; and the fourth is a small rounded nodule.

Articulations.

Articulations.—Its base articulates with the sacrum, and in advanced age becomes blended with it.

THE VERTEBRAL COLUMN.

Vertebral column, how constructed.

General appearance.

The *vertebral column* (columna vertebralis, rachis, spina,) is formed by the bodies of the vertebræ, except those of the head, and is situate along the median line, at the posterior part of the trunk. Anteriorly it presents the form of an irregular pyramid; posteriorly, a series of elongated processes (spinæ), disposed regularly the one beneath the other, from which circumstance the term "spine" is derived. Viewed as a whole, it resembles at first sight the shape of a long bone, but it is very differently constructed. As it receives the weight of the head and trunk, and transmits this to the base on which it rests, it requires to be firm and

It props the head;

* The anterior surface of the coccyx.

resisting, its power of resistance increasing gradually from above downwards. Being the centre of all the movements of the body, it must be as pliant and flexible as a bow, but yet firm, in order to give adequate protection to the spinal cord which it incloses. All these conditions are attained by its being made up of several small pieces united by an elastic substance, the motion permitted between each pair being slight, while the aggregate of all is considerable.

is moveable; and protects the cord.

Its length; does not determine the height of the body.

Length.—The average length of the column, is equal to about two feet two or three inches. Its length does not vary in different persons as much as might be anticipated from a comparison of their stature; the relative height of individuals depending more on the length of the lower limbs than on that of the vertebral column.

Form, double pyramid: other subdivisions.

Form.—Its form is pyramidal—rather it consists of two pyramids joined by their bases; the upper one being formed by the moveable vertebræ, the lower one by the sacrum and coccyx. The upper pyramid, however, instead of tapering regularly from the top to the bottom, becomes narrow in the upper part of the dorsal region; it is most narrowed about the fourth dorsal vertebra. Above this point the column has been held to admit of subdivision into two pyramidal parts, meeting by their bases about the first dorsal vertebra; the apex of one being the vertebra dentata, that of the other the fourth or fifth dorsal vertebra.

Curves, anterior and posterior;

The curves.—When viewed in profile in the natural state, it presents four curves depending, except perhaps the last, on the different degrees of thickness of the inter-vertebral substance in the different regions. The curves are directed alternately backwards and forwards; in the neck and loins the convexity looks forwards, in the back and pelvis it is in the opposite direction (fig. 11 *a*).

lateral; its cause.

A slight degree of lateral curvature is also observable in most cases in the dorsal region, the convexity of which is directed towards the right side. The older anatomists imagined this to be produced by the action of the aorta beating against the left side of the column; but Bichat attributed it to the effect of muscular action, and explained it in the following way:—As most persons are disposed to use the right arm in preference to the left, the body is curved to the left, when making efforts as in pulling, for the purpose of giving an additional advantage to the muscles,

and enabling them to act with more power on the points to which they are attached; and the habitual use of this position gives rise to some degree of permanent curvature. In support of this explanation of the fact, Béclard has stated that he found in one or two individuals, who were known to have been left-handed, the convexity of the lateral curve directed to the left side. A further confirmation of the correctness of this view is afforded by an observation made by Professor Otto.* In a case in which the aorta arched to the right instead of the left side, he found that the curve of the vertebral column had the usual direction; so that the great vessel was connected to its convexity: it is stated, too, that the right arm was more muscular than the left.

Illustrative cases.

Fig. 11. a*

For a detailed examination of its parts, the column will be considered as presenting an anterior and a posterior surface, two lateral surfaces, a base, and a summit, each deserving a particular notice. The part formed by the sacrum and coccyx, having been already sufficiently referred to, may be excluded from consideration in this place.

Anterior surface; its varying breadth and transverse grooves.

The *anterior surface* is broad in the cervical, narrow in the dorsal, and again expanded in the lumbar region; it is marked by a series of transverse grooves corresponding with the centres of the bodies of the vertebræ, and in the fresh state is covered by the anterior common ligament.

*a A plan of the components of the spinal column. The centres of the moveable vertebral segments are numbered from above down; and they are represented at a little distance from one another, as they would be separated by ligamentous substance in the recent state. C. indicates the sacrum with the coccyx below it. A. marks the ridge of the spinous processes; and B. the transverse processes or diapophyses in the dorsal region.

* "Seltene Beobachtungen," Th. 2, S. 61. See also "The Anatomy

Posterior surface; its spines; grooves, with intervals in them.

The *posterior surface* presents along the median line the spinous processes, varying in form and direction, as has been already stated: they are horizontal in the cervical and lumbar regions, and nearly vertical in the dorsal; in the cervical and lumbar regions they correspond pretty exactly with the middle line, but in the back the spines will be observed in many instances to incline, some to one side, some to the other. On each side of these are the vertebral grooves, extending from the base of the skull to the sacrum; their breadth corresponds with that of the laminæ; they are broad but shallow in the neck, and become deep and narrow lower down. Along the grooves are seen the spaces between the laminæ, which in the natural condition are filled up by the yellow ligaments. The breadth of these intervals is very trifling in the neck and in the greater part of the back; it increases in the lower third of the dorsal, and still more in the lumbar region. The interval between the occipital bone and the atlas is considerable, and so is that between the last lumbar vertebra and the sacrum.

Lateral surfaces.

The *lateral surfaces* present the transverse processes, varying in form and character in the different regions; before these are situate the inter-vertebral foramina, and more anteriorly still, in the dorsal region, the articular surfaces which receive the heads of the ribs.

Summit and base.

The *summit* of the column is surmounted by a sort of capital, (the atlas,) which is articulated with the occipital bone, and supports the head. The *base* rests on the sacrum; and by this bone the weight of the trunk is communicated to the lower extremities through the medium of the innominate bones.

Vertebral canal.

Along the entire extent of the column runs the *vertebral canal*, which is broad and triangular in the cervical and lumbar regions, circular and contracted in the dorsal. The canal may be said to expand at its upper extremity into the cranial cavity; its lower end is prolonged into the narrowing canal of the sacrum.

OSSIFICATION OF THE VERTEBRÆ.

Ossification; uncertainty as to the time of its commencement.

General observations on the time when ossification begins.— The process of ossification begins at different periods in the

of the Arteries, with its applications to Pathology and Operative Surgery," by R. Quain, p. 19.

several parts of the skeleton, and it becomes an object to assign to each centre of bony deposit the time at which it appears. This is a subject of considerable difficulty, and a few general remarks with reference to it are necessary before describing the ossification of individual bones.

The accuracy with which the date of ossification may be determined must depend on the exactness with which the age of the embryo is ascertained. But much uncertainty must exist with respect to this point, for the evidence as to the period of conception is not to be fully relied on; and, moreover, the embryo submitted to examination is most commonly in a diseased state, and may have ceased to live some time previous to its separation from the parent. To these sources of uncertainty another may be added: the difference, namely, which actually occurs in the growth of bone in different cases. It seems reasonable that the time of ossification should be influenced by the quality of nutrition; the opinion, however, that there is some variety among the stages of ossification in different individuals, is not founded on such general grounds, but on a comparison one with another of cases which have fallen under my notice, and on the result afforded by contrasting observations accurately made by myself with some which bear the appearance of having been carefully made by others. It is, doubtless, in a measure at least, in consequence of circumstances such as those referred to, that so great a difference prevails between the statements of various observers on the point in question. These considerations lead us to the conclusion, that the period of the commencement of ossification in a given bone does not admit of being set forth with absolute certainty, especially as regards those bones in which a process begins at very early periods. As to this part of the subject, therefore, we must be content with an approximation to exactness.

Causes.

Conclusion as to the time.

But the relation which the time of the appearance of bony matter in one piece of the skeleton has to the time of its appearance in another, admits of being stated with more accuracy; and it will, in our progress, be referred to whenever it shall appear material. To exemplify what has been said, it may be added, that we may not be able to state with rigid accuracy when bone makes its appearance in the several divisions of the vertebral column, or in the clavicle: but we can with confidence determine which of them precedes the other in its ossification.

Relation of the times of commencement in different bones.

Ossification of vertebræ. Division of the subject.

The observations on the growth of bone in the vertebræ will be arranged under three heads, as follows :—*a*. The first will contain an account of the common characters of the ossification of a vertebra. *b*. Under the second head will be placed the peculiarities that occur in the growth of certain vertebræ or parts of the vertebral column. *c*. Lastly, the progress of ossification in the column generally will be reviewed.

OSSIFICATION OF A VERTEBRA.

COMMON CHARACTERS.

The process in a single vertebra.

Exclusive of certain exceptional cases, to be afterwards noticed, each vertebra is formed of three principal pieces, to which five small epiphyses are added at an advanced period, and as if for the completion of the bone.

Fig. 12.*

Three principal pieces.

Of the principal pieces two are destined for the formation of the arch and the processes which project from it (fig. 12,[1 2]). The body of the vertebra is produced from the third (fig. 12,[3]).

Time of commencement.

Osseous substance is first observable in the vertebræ about the seventh or eighth week from the time of conception, and it commences in the arch (but not invariably) a little before the body.

Lateral pieces for the arch.

The osseous granules for the arches make their appearance on each side at the situation from which the transverse processes project ; and from this place the formation of bone extends in different directions,—forwards to the body, inwards to the spine, and outwards to the transverse process, as well as into the articular processes ; and thus two irregularly-shaped angular pieces of bone are produced.

* A. The three principal pieces of the vertebræ are seen to be distinct one from another. B. The lateral pieces have joined behind. The spinous and transverse processes remain cartilaginous at their ends. The arch is still separable from the middle anterior piece, and the cartilage having been removed from the body, the surface of this is rounded, rough, and fissured.

1, 2. The lateral pieces. 3. The anterior part for the body. * Line of separation between the lateral pieces and the anterior.

The single nodule from which the greater part of the body of the vertebra is formed appears in the middle of the cartilage. The body.

At the usual period of birth the three primary pieces are still separate. The process of union commences in the first year after birth. It commences with the lateral pieces, which, at the period mentioned, begin to join behind—in the situation of the spinous process; and by this junction the arch of the vertebra is constructed. Condition at birth. Union begins with the arch.

In the course of the third year the central anterior part joins the arch on each side in a few of the vertebræ, and the junction is effected in such a manner that the body is formed from the three original centres of ossification. Each end of the arch contributes a small angular portion (fig. 12, B). The three pieces joined. Body of vert. how formed.

Epiphyses.—The spinous process projects backwards from the point at which the lateral pieces have joined, and no further change occurs except the general increase of the different parts of the vertebra and the extension of ossification from the primary pieces, till about the age of puberty. If the bone is examined before that period it will be found, on stripping the cartilaginous ends from the transverse and spinous processes, that the cells of the osseous structure are exposed; Epiphyses. State of the bone before they are added;

Fig. 13.*

* These figures are intended to show the epiphyses of a vertebra. That marked C represents a dorsal vertebra. The epiphyses of the processes are drawn slightly away from the rest of the bone. D. The arch and processes of a lumbar vertebra, with the epiphyses. These are somewhat elongated, corresponding to the processes which they cover, but the bone having been viewed from above, only their ends came under the artist's eye; and this circumstance will account for their small size in the drawing. E. A front view of the body of a vertebra to exhibit the thin epiphyses which belong to its upper and lower surfaces. 4, 5. The ends of the transverse processes. These processes are not numbered in figure D. 6. Spinous process. 7, 8. The two epiphyses of the body; the flat surface of one is seen in figure C; the edges of both are marked in figure E. 9, 10. Epiphyses of the articular tubercles of a lumbar vertebra.

and on separating the bodies of the vertebræ, the one from the other, the cartilages, which still belong to their upper and lower surfaces, remain adherent to the intervertebral substance, and the osseous part is rough, fissured, and wanting at its circumference the angular shape and dense external covering which belong to the perfect bone (fig. 12, B).

their position, and the times of their appearance;

At the age of about sixteen years, separate osseous points begin to be observable in the cartilaginous ends of the transverse and spinous processes, and they ultimately cover and complete the processes (fig. 13, C,[4 5 6]). At a later period, soon after twenty years, two thin circular plates begin to be formed, one on the upper, the other on the lower surface of the body, at its circumference (fig. 13, C. E,[7 8]).

their junction; and completion of the vertebra.

All the secondary or accessory pieces having joined, the bone is completed before the thirtieth year.—The epiphyses of the transverse and spinous processes usually join before those which belong to the body of the vertebra.

Arrangement of the osseous structure.

The *arrangement of the osseous structure* is not the same in the different parts of a vertebra. The arch and the processes projecting from it have a thick covering of compact tissue. The body, on the contrary, is composed nearly altogether of spongy substance: this part of the bone, when sawed through, will be found to consist of cells bounded by thin plates of bone; and it contains large canals for the lodgment of veins. The canals differ somewhat in disposition in different cases, but they will be found to have the same general direction from behind forward, radiating with more or less regularity from the large foramina on the posterior aspect of the body.

Cells and canals in the body.

PECULIARITIES IN THE GROWTH OF CERTAIN VERTEBRÆ.

Peculiarities in certain vertebræ.

The vertebræ which require separate notice, by reason of some peculiarities in their manner of growth, are the first, second, and last cervical; those of the lumbar region; together with the sacrum and coccyx.

THE ATLAS.

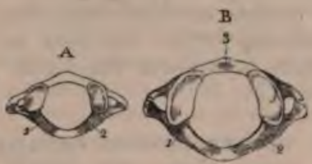
Principal pieces.

The *atlas* is usually formed from three principal osseous nuclei. The ossification of the lateral parts of the vertebra (fig. 14,[1 2]) commences at a very early period.

State at birth.

At birth, the interval between the articular processes of the vertebra at the anterior part of the bone is altogether cartilaginous, and there is a smaller space posteriorly between the two lateral pieces (fig. 14, A).

Fig. 14.*



Anterior part or body.

The nucleus for the anterior part (body, fig. 14,[3]) appears soon after birth, very rarely, if ever, before that period. But the ossification in this spot sometimes proceeds from more than one centre. According to Béclard, two occur in the proportion of one instance in four or five; and Albinus† and J. F. Meckel‡ observed each a case in which there were three granules in the situation mentioned.

The neural arch.

The neural arch is formed by the junction of the lateral pieces, between the second and third years; and it joins the anterior part at the age of five or six years.

Epiphysis.

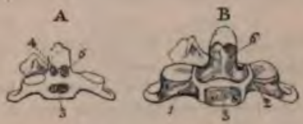
There is frequently a small epiphysis on the posterior tubercle, or spine.

THE AXIS.

Axis; its peculiarities in the body and odontoid process.

The formation of the arch of the axis corresponds with that of the other vertebræ. The peculiarities occur in the anterior part, which is developed from three points or centres:—one being destined for the lower part of the body, the two others for the odontoid process and the upper part of the body (fig. 15, [3 4 5]).

Fig. 15.§



* The atlas is seen from above in both figures. A. The lateral pieces are separated by a cartilaginous interval in front and behind. B. This figure is intended to show a nucleus in the anterior part. It has been modified from one given by Kerckringius in his 37th plate.

† "Icones Ossium Fœtûs," p. 68.

‡ "Archiv.," &c. Band 1, S. 648, and Taf. vi. 1815.—Meckel's case had the additional peculiarity of a separate nucleus interposed between the lateral pieces posteriorly.

§ The anterior surface of the axis is represented in both drawings.

These nuclei appear about the sixth month of fœtal life, the lower single one preceding the others by a short space of time. The two superior, lying on the same horizontal plane, enlarge and join before birth. At this period the axis consists of four pieces—the two lateral and two anterior (B, [1 2 3 6]). The body and odontoid process form a single mass about the fourth year (second or third, Béclard).

State at birth,

and fourth year.

THE SEVENTH CERVICAL VERTEBRA.

Last cervical; its transverse process.

The anterior root (parapophysis) of the transverse process of this vertebra is frequently, if not constantly, formed from a separate osseous nucleus, which unites on the one hand to the body, and on the other to the posterior root (diapophysis) of the same process. The time of the appearance of this point of ossification is stated by Béclard to be the second month of fœtal life, but my own observation would lead me to set it down for a later period—the sixth month. It is united to the rest of the bone about the fifth or sixth year.

Cervical rib.

Occasional instances occur of the continuance of this process as a separate bone, and in such cases,—being lengthened to an extent which varies in different instances,—it forms what has been termed a cervical rib.*

Transverse processes of other cervical vertebræ.

Meckel † also observed separate centres of ossification in the corresponding parts of the transverse processes of the second, fifth, and sixth cervical vertebræ. These were, however, of small size, and in some instances did not form any part of the foramen for the vertebral artery.

A. The three nuclei for the anterior part are here shown. In B. four pieces are seen connected by cartilage.—1, 2. The lateral pieces. 3. The nucleus for the lower part of the body. 4, 5. Those for the odontoid process and the upper part of the body. 6. The single piece resulting from the junction of 4 and 5.

* Two examples of the cervical rib are described in "The Anatomy of the Arteries, with its applications," &c., by R. Quain, pp. 149 and 187, and plate 25. J. F. Meckel ("Archiv.," &c. B. 1, Taf. vi. 1815.) has figured a case resembling one of those in the circumstance of the end of the cervical rib being connected to a prominence on the first dorsal rib.

† Loc. citat.; and "Journal Complément. du Dict. des Sciences Med," vol. ii. p. 218.

THE LUMBAR VERTEBRÆ.

In addition to the centres of ossification which belong to the vertebræ generally, in the lumbar region each bone has two small epiphyses for the "tubercles" (diapophyses) that project from its superior articular processes (fig. 13. D,[9 10]). Lumbar vertebræ have two additional epiphyses.

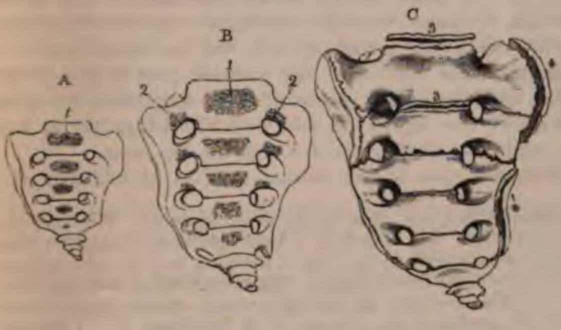
The transverse process (parapophysis) of the body of the first lumbar vertebra is sometimes observed to be developed altogether from a separate centre. The persistence of a process so formed, as a separate piece, would account for the existence of a lumbar rib,—examples of which have occasionally been met with. Lumbar rib; how formed.

OS SACRUM.

The *sacrum* results from the union of five vertebræ. In the manner of their ossification these do not at an early period differ from that of the vertebræ in other parts of the column. Sacrum; its vertebræ at first resemble others.

The lateral pieces join behind in each to constitute the arch, and subsequently become united to the body in the The order in which the parts of the vertebræ unite.

Fig. 16.*



manner of other vertebræ; but the order in which this junction occurs in the different pieces is deserving of notice.

* These figures display different stages of the ossification of the sacrum. Fig. A., taken from a fœtus which had not reached the sixth month, contains in front only the nuclei for the bodies. In fig. B. (from a child at the usual period of birth) three additional nuclei are

The process of union commences in the lowest vertebra, and progressively extends upwards. The parts of the fifth are joined about the second year; while those of the first are not blended into a single piece before the fifth or sixth year.

Epiphyses: those of the bodies of the vertebræ.

The sacral vertebræ remain separate one from another, being united only by cartilage and the inter-vertebral substance, till about the sixteenth year. At this period epiphyses begin to form on the middle part or body of each sacral vertebra, which are similar to those on the like part in other vertebræ (C, $^{3\ 3}$).

The order in which the sacral vert. join.

About the time last mentioned (the eighteenth year) the fourth and fifth vertebræ are joined the one to the other; and the process of union gradually proceeding upwards (fig. 16. C), reaches the first two from the twenty-fifth to the thirtieth year.

Side piece of sacrum,

Lateral part of the sacrum.—The portion of the sacrum external to each lateral row of apertures, is constructed of processes that grow separately from the rest of the bone,

formed of transverse processes;

and correspond with the transverse processes of the lumbar vertebræ, as well as with the anterior root of the so-called transverse processes in the neck.

time of their appearance, in first four vertebræ.

These pieces or transverse processes of the bodies of the vertebræ (parapophyses) appear as osseous points between the sixth and the ninth month, there being two for each of the first four vertebræ;* and the centres are deposited from above down—the highest appearing first, and the lowest last.†

How they join, and the time.

Between the third and the seventh year they join the bodies and the neural arches of their respective vertebræ, and about the eighteenth year they blend together to form the solid piece that articulates with the hip bone.

Epiphysis to side piece.

Each side piece of the sacrum receives in addition at a

deposited on each side, close to the sacral foramina. The coccyx has no ossific point. Fig. C. is from a body aged about twenty-five years. Epiphyses are visible on the sides of the bone, and are still apparent on the body of the first vertebra. The lower vertebræ have completely joined, while the first two are but partially united.—1. The body. 2. Nuclei peculiar to the sacrum. 3 3. Epiphyses for the body of a sacral vertebra. 4 4. Lateral epiphyses.

* No separate centre has yet been seen for the fifth sacral vertebra, and it is therefore supposed that the transverse process of this segment is produced from the centre for the ossification of the body. An account of the growth and nature of the processes will be found in the "Report of the Seventh Meeting of the British Association," in a communication by Hugh Carlile, M.B., T.C.D., 1837.

† These processes are sometimes called "sacral ribs."

later period a thin flat plate or epiphysis, which appears to be divided into two parts—one reaching over the first three vertebræ, and the other connecting the last two ($c^{4\,14}$). The ossification of this lateral epiphysis begins about the eighteenth or twentieth year, by several irregular granules, which increase and coalesce; and it ends at the thirtieth year, when the epiphysis becomes part of the bone, and the growth of the sacrum is completed. As the sides of the sacrum are formed by the enlargement and union of the transverse processes of its vertebræ, so may the lateral epiphyses be taken to represent the epiphyses of those processes,—altered indeed, and, as it were, fused together.

Time of appearance; when joins the bone.

OSSIFICATION OF THE COCCYX.

Each of the coccygeal vertebræ is usually ossified from a single centre; but occasionally one of the first three is found to contain two granules, placed side by side. A nucleus appears in the first piece about the time of birth, or in the course of a few months after (fig. 16, B. note). The periods assigned by Béclard for the ossification of the other coccygeal vertebræ are the following, viz. for the second, from five to ten years; for the third, from ten to fifteen; and for the fourth, from fifteen to twenty. As age advances the bones unite in pairs, the first to the second, the third to the fourth; and at a later period of life, they are formed into a single piece by the union of the second and third. Lastly, the coccyx becomes joined to the end of the sacrum in old age, and this is said to occur least frequently in the female.

Coccyx; usually one centre for each vert.

Times of their appearance.

Union of the pieces.

THE PROGRESS OF OSSIFICATION IN THE VERTEBRAL COLUMN GENERALLY.

In the observations on the growth of a single vertebra the date at which the osseous points appear for the first time in the column has been mentioned; but inasmuch as the same parts do not begin to ossify simultaneously throughout the spine, it becomes necessary to review the progress of ossification in the vertebral column as a whole, for the purpose of indicating the differences that exist in these respects.

Like parts ossify at different periods along the vert. column.

The ossification of the lateral pieces begins at the upper

The lateral pieces,

end of the column, and gradually proceeds downwards to its opposite end.

and the bodies in various situations.

In the bodies of the vertebræ the deposit of bone first occurs in the lower part of the dorsal region (about the ninth dorsal vertebra), and from this the process is extended upwards and downwards, reaching last of all the atlas at one extremity, and the coccyx at the other; for both these, as has been previously stated, do not ossify till after birth. But it is to be borne in mind, that though the nuclei of the lower dorsal vertebræ appear first, they do not long continue the largest. As growth advances they are surpassed in size by nuclei below them, and in the full-grown fœtus these are largest in the lower lumbar and the first sacral vertebræ. In fact, their relative size at this period corresponds with that of the vertebræ.

THE BONES OF THE SKULL.

The skull is composed of four vertebræ.

The skull, like the spinal column, is formed of a given number of vertebral segments, which however are all immovable, and specially modified for the reception of the brain and the organs of the senses. In it there are four vertebræ, viz., an occipital, a parietal, a frontal, and a nasal.*

It is spheroidal in shape,

Considering for the present the skull as a compound of a number of separate pieces or bones, it has a spheroidal figure, compressed on the sides, but broader behind than before, and is supported by its base on the vertebral column.

and consists of cranium and face.

It is divided by anatomists into two parts, the cranium and the face. The former is composed of eight bones, viz. the *occipital*, two *parietal*, the *frontal*, two *temporal*, the *sphenoid*, and the *ethmoid*.

The bones of each.

The latter is made up of fourteen bones, viz. two *superior maxillary*, two *malar*, two *ossa nasi*, two *ossa palati*, two *ossa unguis*, two *inferior turbinated* bones, the *vomer*, and the *inferior maxilla* or mandible; the frontal bone is so situate as to be common to the cranium and face.

Other bones.

The bones of the ear and the teeth are not included in this enumeration, as they belong rather to special organs than to the skeleton considered as the frame-work of the body.

THE OCCIPITAL BONE.

Occipital bone;

The occipital bone, figs. 17 and 18 (os occipitis), is situate

* The number is stated differently by anatomists; but the enumeration of Professor Owen is here taken.

at the posterior part of the base of the skull, and is broad behind, but much narrowed before.

Fig. 17.*

how placed in position.

To place the bone in its natural position, hold it so that the great foramen and the articulating processes beside it shall look directly downwards; the thick process in front of the foramen will then project forwards into the base of the skull, whilst the broad expanded part behind it arches upwards and a little forwards, forming the posterior part of the cranial cavity.

The outer surface.

External surface: this is convex in its general outline, and presents a little above its centre a rough prominence,[1] the *external occipital protuberance;* but between this and the top of the bone it is smooth. Extending obliquely outwards at each side from the protuberance, is a rough line,[2] called the *superior curved line*, to distinguish it from another, which is lower down between it and the great foramen, called the *inferior curved line;*[3] both are prominent, and give attachment to muscles, as also do the rough depressions between them. These are crossed by a vertical raised line, the *external occipital crest* or *spine*,[4] extending forwards from the protuberance to the foramen.

External occipital protuberance.

Super. curved line.

Inferior curved line.

External occipital crest.

Foramen magnum.

The *occipital foramen*[5] (foramen magnum), which is of an oval figure (its long diameter extending from before backwards), gives transmission to the spinal cord, the vertebral arteries, and the spinal accessory nerves.

Condyles.

At each side of the foramen, but near its anterior part, are situate the articulating processes [6 6] (*condyles*), two oblong

* External or cutaneous surface of the occipital bone. 1. External occipital protuberance. 2. Superior curved line. 3. Inferior curved line. 4. External occipital crest. 5. Foramen magnum. 6. Condyles. 7. Surface for the attachment of ligaments. 9. Posterior condyloid foramina. 10. Rough projection corresponding to the transverse process of a vertebra.

eminences, which articulate with the first vertebra. These converge from behind forwards; their inferior surface, which in the fresh state is smooth, covered with cartilage, and convex in its general outline, looks downwards and outwards, and is adapted for moving on the concave surface presented by the articulating processes of the atlas. The inner border of each condyle[7 7] is rough, and receives the insertion of the check ligaments, which extend up from the odontoid process of the axis; the outer border, depressed and not so well marked, gives attachment to the ligament connecting it with the atlas.

Condyloid foramina, and what they transmit.

In front of each condyle is a foramen, fig. 18,[8 8] *anterior condyloid*, which looks outwards and forwards, and transmits the hypoglossal nerve; behind each is also a large pit, in which is sometimes found a foramen[9 9] (*posterior condyloid*), which gives passage to a vein and a small artery: sometimes a foramen exists at the one side, and not at the other. External to each condyle is a rough nodule,[10 10] which overhangs the transverse processes of the vertebræ, of which it may be regarded as the representative; it gives insertion to the rectus lateralis muscle.

Fig. 18.*

The inner surface. Crucial ridges.

The *internal surface* of the bone (fig. 18*) is marked by two crucial raised lines or ridges (lineæ cruciatæ eminentes), —one vertical, extending from the upper angle of the bone to the large foramen; and the other transverse, crossing the middle. These intersect towards the central point,[11]

* The occipital bone: its internal or cerebral surface. 5. Foramen magnum. 8. Anterior condyloid foramina. 9. The superior angle. 11. Internal occipital protuberance. 12. Superior occipital fossæ. 13. Inferior occipital fossæ. 14. Upper division of the crucial ridges grooved for the longitudinal sinus. 15 15. Transverse parts of same grooved for the lateral sinuses. 16. Internal occipital crest. 17. is opposite the basilar groove. 18. Groove for the end of the lateral sinus. 19. Basilar process. 20. Jugular eminence.

(internal occipital protuberance,) and mark off four broad pits, of which the upper pair [12 12] (superior occipital fossæ) receive the posterior lobes of the brain ; and the lower [13 13] (inferior occipital fossæ) lodge the lateral lobes of the cerebellum : the superior line [14] and the two transverse ones [15 15] are generally grooved, and correspond with the course of the longitudinal and lateral sinuses. The inferior one,[16] which is commonly named the internal occipital spine or crest, gives attachment to the falx cerebelli. The anterior border [17] of the foramen magnum is slightly excavated, and becomes continuous with the *basilar groove*, a shallow excavation on the surface of the basilar process, which supports the medulla oblongata ; close to the margin of the foramen, are the anterior condyloid foramina, and a little external to these are two fossæ,[18 18] marking the termination of the lateral sinuses.

Internal occipital protuberance.

Occipital fossæ.

Internal occipital crest.

Basilar groove.

The thick triangular process [19] which projects forwards into the base of the skull from the foramen, is called the *basilar* process. Its margins are rough and contiguous to the pars petrosa of the temporal bone ; its under surface presents slight depressions for the insertion of muscles ; and the upper one the shallow groove just noticed. Along the lateral margin of this groove, and close to the edge of the bone, is a linear depression, which forms part of the sulcus for the inferior petrosal sinus.

Basilar process.

Petrosal groove.

The *border* of the occipital bone is serrated, and its upper angle or point [9] is often interrupted by bony islets (ossa triquetra—Wormiana). Inferiorly the serrated edge terminates at each side in a prominent piece of bone, [20 20] the *jugular eminence*, which surmounts an excavation (jugular notch or fossa) contributing with the temporal bone to form the foramen lacerum jugulare.

The margin.

Jugular eminence.

In some parts the occipital bone has considerable thickness, especially at the occipital protuberance and the anterior part of the basilar process. In the lower occipital fossa it is very thin.

Various thickness.

Articulations.—The occipital articulates with six bones, viz. with the two parietal and the two temporal by its border —with the sphenoid by its basilar process—and with the atlas by the condyles.

Articulates with six bones.

Ossification of the occipital bone.—During a considerable time before and after birth this bone consists of four pieces, —namely, the posterior, proper occipital or proral part : the anterior or basilar : and the two lateral or condyloid (fig. 19, B).

Ossification in four primary pieces.

These pieces meet around the foramen magnum. Each of them requires separate notice.

Fig. 19.*

Period of commencement. The posterior part has four nuclei.

The ossification of the occipital bone precedes that of the vertebræ in the time of its appearance. It begins with the proper occipital part. For this division there are four nuclei, which are placed in pairs above and below the occipital protuberance (fig. 19, A¹ ²). The two inferior nuclei appear first, and soon join into a single piece. The superior pair of granules unite one to another also, and the two pieces, thus resulting from the four primitive centres, joining speedily, form a single mass.†

* The occipital bone at different periods of its growth,—namely, about the tenth week and at the ordinary period of birth. The figure marked A, has been copied from one published by Meckel in his "Archiv." (B. 1, Taf. vi.) The four nuclei of the posterior or proral part of the bone are shown,—the two lower being the more advanced. Germs of ossification are observable in the condyloid pieces. There is none apparent in the basilar part.

† J. F. Meckel ("Handbuch der Menschlich. Anat." B. 2, § 543) assigns eight primitive granules to this part. Four he makes to correspond with those described in the text. Of the other four, he places two close together at the upper angle of the bone; and the remaining two, one at each side, opposite the transverse crucial line, in its lateral angles.

Judging from the usual appearance or texture of the upper and lateral parts of the occipital bone at early periods of its growth, it seems to me to be most probable that the four points found by Meckel in its angles do not occur constantly, or even generally; and if so, may they not be regarded as the centres of some of those separate pieces which are often to be met with in the neighbourhood of this bone? I

Soon after the posterior part of the bone, the two condyloid pieces begin to ossify (A, [b]), and they are followed by the basilar portion. Each is formed from a single central point. It is to be observed, that the condyles of the occipital bone are not supported altogether on the pieces named condyloid ;—a small portion of each is borne by the basilar part.

The condyloid and basilar pieces have each one nucleus.

At birth the four pieces are distinct (fig. 19, B, [a b c]), and the posterior one is partly divided by deep fissures (two being horizontal and one vertical) extending from the circumference towards its middle.

State of the bone at birth.

About the fourth year of age the process of union begins by the junction of the posterior and the two condyloid pieces, and the bone is a single piece about one or two years later. Subsequently the occipital unites with the sphenoid bone, so that, in the adult, the basilar process must be sawed across in order to separate them. And it was in consequence of this circumstance that Sœmmerring described them as a single bone under the name spheno-occipital or basilar.

The period at which the pieces join.

Union with the sphenoid.

THE PARIETAL BONE.

The parietal bones (ossa parietalia, verticis, bregmatis) form a principal part of the roof of the skull; they are of a square form, convex externally, concave internally, and present each two surfaces and four borders.

Parietal bones; their position and shape.

Fig. 20.*

The bone may be placed in its natural position by putting forwards and downwards the thinnest and most pointed angle,[9] and turning outwards the convex surface.

Bone of one side distinguished.

The external surface, fig. 20, rises towards its middle,

External surface.

would add, as facts bearing on the question, that an independent lateral nucleus existed only on one side of the preparation by which Meckel seems to have been influenced in forming his opinion on the number of the centres of ossification (see the figure in his "Archiv. für die Physiolog." B. 1, Taf. vi.—1815); and that the upper part of the bone is occasionally altogether detached.

* The parietal bone; its convex surface. 1. Parietal eminence.

Parietal eminence, where it presents a slight elevation, called the *parietal eminence* ;[1] below this is a curved line,[2 2] continuous with the temporal ridge, and bounding a flat surface (planum semicirculare),[3] which forms a part of the temporal fossa. At the upper and back part of the bone, usually about two lines from the sagittal suture, is a small hole[4] (foramen parietale), which transmits a communicating vein : its position is exceedingly variable ; even its existence is not constant.

and foramen.

Internal surface. The internal surface of the bone, fig. 21, is marked by branching lines (sulci meningei),[5 5 5] corresponding with the course of the middle meningeal artery, and by depressions (impressiones digitatæ) for the convolutions of the brain. Towards its middle is a hollow,[6] the "parietal fossa," corresponding with the eminence (parietal) on the outside. Along the superior border is a slight sulcus,[7 7] which with a similar one in the corresponding bone forms a groove adapted to the course of the longitudinal sinus ; and in the same situation in most skulls (particularly those of old persons) are some small pits (foveæ glandulares),[8] corresponding with the so-named glandulæ Pacchioni.

Grooves, depressions,

and fossa.

Fig. 21.*

Other markings.

Margins. The superior border is straight, and articulated with its fellow by a series of serrations : the inferior border, concave and bevelled off at its outer margin, is overlapped by the squamous portion of the temporal bone ; the anterior unites with the frontal bone, and the posterior with the occipital.

2. Semicircular line. 3. Planum semicirculare. 4. Parietal foramen.

* The internal or cerebral surface of the parietal bone. 4. The parietal foramen. 5. Grooves for the middle meningeal artery. 6. The parietal fossa. 7. "Sulcus sinûs longitudinalis." 8. "Foveæ glandulares." 9. The anterior inferior or sphenoidal angle. 10. The posterior inferior or mastoid angle. 11. "Sulcus sinûs lateralis."

The anterior inferior angle [9] dips down to the great wing of the sphenoid bone, and presents a groove [9] internally for the middle meningeal artery: the posterior inferior angle [10] articulates with the mastoid part of the temporal bone, and is marked internally by a small part [11] of the groove which lodges the lateral sinus. Angles.

Articulations.—It articulates with its fellow of the opposite side, and with the frontal, the sphenoid, the temporal, and the occipital bones. Connection with other bones.

Ossification.—Its growth proceeds from one ossific centre, which corresponds with the parietal eminence, and is first perceptible about the same time as the ossification begins in the spinal column. At birth the antero-superior angles of these bones are not developed; so that there exists an interval between them and the still divided os frontis, which is called the "fontanelle" (fons, bregma). Ossification.

THE FRONTAL BONE.

The frontal bone, fig. 22 (os frontis, coronale), situate at the anterior part of the skull, and upper part of the face, is divisible into two parts (frontal and orbital), differing in size and position: one of these extends upwards towards the vertex of the skull, forming three-fourths of the bone; the other, inferior and horizontal in its direction, is placed in the roof of the orbits. Frontal bone; division of.

Fig. 22.*

To place the bone in its natural position, hold it so that the orbital plates shall look downwards, and the smooth convex surface forwards. Natural position out of body.

* The frontal bone viewed from before. 1. Frontal eminence. 2. Superciliary ridge. 3. Orbital arch. 4. External angular process of the orbit. 5. Internal angular process of the orbit. 6. Supra-orbital notch. 7. Glabella. 8. Nasal spine. 15. Part of the temporal fossa.

Frontal part; its convex surface. Frontal eminence. Superciliary ridge. Orbital arch,

The frontal part.—Its *external surface* is smooth, and presents on each side a slight elevation,[1 1] named *frontal eminence*, which corresponds with the most prominent part of the forehead: below this is an arched depression, bounded below by a prominent curved line,[2 2] called the *superciliary ridge*, or arch, which is more or less prominent in different individuals. Immediately below this is the margin of the orbit (*orbital arch*),[3 3] which is better defined towards its outer part, where it curves down to the malar bone, and forms the external angular process,[4 4] than at its inner portion,[5 5] where it gradually subsides towards the root of the nose. Towards the inner third of the orbital arch is a small foramen[6 6] (*supra-orbital*), or sometimes a notch crossed by a ligament, which transmits the supra-orbital nerve and artery.

and foramen.

Glabella.

Between the superciliary ridges is the *nasal eminence*,[7] or *glabella*, which is prominent in proportion to the size of the frontal sinuses: it is bounded inferiorly by a rough surface which articulates with the nasal bones and the ascending processes of the superior maxillæ. From this surface a flat thin process,[8] called the *nasal spine*, projects downwards in the median line, and on each side of it, on the under aspect, is a groove corresponding to the nostril; it articulates in front with the nasal bones, and behind with the perpendicular lamella of the ethmoid.

Nasal spine.

Fig. 23.*

Concave inner surface

The *internal surface* of this part of the bone is concave, and on it along the median line is a groove (sulcus frontalis), fig. 23,[9] corresponding with the longitudinal sinus. The margins of the groove gradually approach each

is grooved.

* The frontal bone from behind—its concave or cerebral surface. 9. "Sulcus frontalis." 10. "Foramen cæcum." 11, 12. Anterior and posterior internal orbital grooves. 13. "Fovea trochlearis." 14. Lachrymal fossa. 16. Openings of the frontal sinuses.

other towards the forepart of the bone, and in some cases unite so as to form a ridge (crista frontalis); but in others the groove, narrowed almost to a line, continues apparent down to a hole in that position. In either case the falx is attached along this line. The groove terminates in front in a minute foramen,[10] called *foramen cæcum*, from its having been supposed to be merely a cul-de-sac, but it is in reality pervious, and lodges a small spur-like process of the dura mater, and transmits a vein which enters the sinus from the nasal fossæ. Foramen cæcum.

The *orbital plates* or processes are smooth and concave at their inferior surface; the superior or cerebral is convex, and marked more or less in different instances by elevations and depressions corresponding with the sulci and convolutions of the anterior lobes of the brain which rest upon them. They are separated by a deep excavation (incisura ethmoidalis), which receives within it the cribriform plate of the ethmoid bone, and round whose margins are several cells that complete the cavities lodged within the lateral parts of the last-named bone. In this margin may also be observed two slight grooves which assist to form two foramina[11 12] (*anterior* and *posterior orbital*), common to the frontal and ethmoid bones, whose contiguous margins enter into their formation. The anterior one transmits the nasal twig of the ophthalmic nerve, and the anterior ethmoidal vessels; the other, the posterior ethmoidal artery and vein. Each orbital plate is bounded externally by a thick well-marked prominence,[4 4] called the *external angular process;* and internally by a depressed and smooth one (*internal angular process*). Near the inner one is a slight depression,[13] to which the cartilaginous pulley of the trochlearis muscle is attached, and which is sometimes named *fovea trochlearis*. Near the outer process and within the orbit, is a depression[14] for the lodgment of the lachrymal gland; the external side of this process is slightly hollowed, fig. 22,[15] and constructs part of the temporal fossa. Orbital part. Ethmoidal fissure and cells. Grooves for foramina. Angular processes, and trochlear pit.

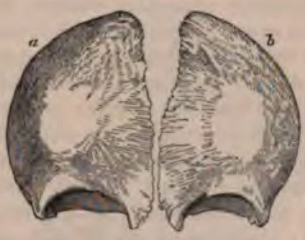
The thickness of the frontal bone varies considerably in different parts. The orbital plates are thin and translucent; and the nasal and external angular processes are thick and prominent. The upper or broad part is thinner at the frontal eminences than elsewhere, if these are well-marked so as to indicate a full development of the underlying cerebral parts. In childhood the two tables are separated only by the spongy texture or diploë, as in other bones; but, in adult age, an interval exists between them at the Various thickness. Frontal sinuses;

period of their formation. middle line over the nasal process, and extends outwards for some way under the superciliary ridges. This interval, the extent of which varies in different individuals, is divided by a bony partition into two parts or cavities,[16 16] called the *frontal sinuses*; these are lined by mucous membrane, and communicate with the cavity of the nose.

Connections with other bones. *Articulations.*—The frontal articulates with twelve bones. Superiorly with the two parietal; laterally and behind with the sphenoid; inferiorly with the ethmoid, with the nasal bones, with the ossa unguis, with the ascending processes of the superior maxillary bones, and with the malar bones. Peculiar mode of articulation. The mode of articulation differs in different parts of its circumference. Thus, the superior border is found to overlap and rest on the parietal bones, whilst towards the lateral and inferior parts the exterior table of the bone is bevelled off, and is covered by the parietal. The posterior border of the orbital plates, straight and squamous, is in a manner inserted between the margins of the two alæ of the sphenoid bone, with each of which it articulates.

Ossification. Two points. *Ossification.*—This bone begins to ossify before the vertebræ, from two osseous points, which appear at the orbital arches. The lateral pieces formed by the spreading of the ossification are quite distinct at birth (fig. 24,[a b]). They afterwards become united along the middle by a straight suture, which runs from the top of the head, where it is continuous with the suture in that position, down to the nose. Halves join at different times. The suture is obliterated within a few years after birth, but the period varies in different cases, and in some instances it is found to remain during life.

Fig. 24.*



THE TEMPORAL BONE.

Temporal bone; The temporal bones, two in number, are so named because they occupy that part of the head on which the hair first

* From the frontal bone of a fœtus born a short time before the usual period of birth.

becomes white, indicating thus the ravages of time (*ossa temporis*).

The *temporal* bone, figs. 25 and 26 (os temporis), is placed at the side and base of the skull. When viewed in its natural position, it presents two portions, one at the side of the skull towards the middle and lower part, which is flat and vertical in its direction; whilst the other is horizontal and projects inwards so as to be wedged between the occipital and sphenoid bones. But to facilitate its description, it may be divided into three parts, of which one is superior, flat, scale-like, and named the squamous portion (squama, a scale); another posterior, thick at its base, but tapering downwards like a nipple, the mastoid part; the third, called petrous from its hardness, is internal and intermediate, projecting into the base of the skull. Position in the skull. Division into three parts.

Fig. 25.*

In order that the bone may be held in its natural position whilst it is being learnt, put downwards and backwards the nipple-shaped part, and outwards the smoothest surface of the squamous part. Right known from left bone.

A. The *squamous* portion [1] (pars squamosa), by its external surface, which is smooth, forms part of the temporal fossa, and is bounded above by an arched border, below by a horizontal process called "zygoma." The inner surface, fig. 26,[2] of the squamous part of the bone, slightly concave in its general outline, is marked like the other bones of the head by cerebral impressions, and by slight linear grooves Squamous part is smooth outside, with a process; but pitted and grooved inside.

* Figures 25 and 26 show respectively the outer and the inner surface of a temporal bone of the right side. 1. Squamous part; its external surface. 2. The internal surface of the same part. 3. Zygoma. 4, 5. Roots of the zygoma. 6. Tubercle for the external lateral ligament. 7, 8. Parts of one of the roots of the zygoma. 9. Fissure of Glaser. 10. Mastoid part. 11. Digastric fossa. 12. "Sulcus sinûs lateralis." 13. Mastoid foramen. 14. Small occipital groove. 15. Petrous part. 18. Carotid canal. 19. Anterior surface of the petrous part. 20. Depression for the Gasserian ganglion. 21. Meatus auditorius internus. 22. Opening of the aqueduct of the vestibule. 23. Rough surface on the inferior aspect for the attachment of muscles. 24. Jugular fossa. 25. Styloid process. 26. Its vaginal process. 27. Stylo-mastoid foramen. 28. Superior petrosal groove. 29. Eustachian tube. 30. Opening of the aqueduct of the cochlea.

Margin scale-like. for branches of the middle meningeal artery. Its upper edge is bevelled off so as to form a thin scale which overlays the parietal bone.

Fig. 26.*

The zygoma; The *zygoma*,[3] or zygomatic process (ζευγνυμι, to connect or yoke together), forms a yoke connecting the temporal with the malar bone; under this the temporal muscle passes. **shape,** It is broad posteriorly at its base, where it projects outward from the squamous part of the bone, but soon narrows, and turns forward. **surfaces, and margins;** Its outer surface is convex and subcutaneous, the inner surface is concave and bounds the temporal fossa. The superior margin, very thin, gives attachment to the temporal fascia; the inferior one is thicker and shorter, owing to the end of the process being bevelled off so as to rest on the malar bone, with which it articulates. At its base the upper surface is concave and supports the posterior border of the temporal muscle. Underneath it is the hollow for the reception of the lower jaw; here it presents two roots, **limits the articular cavity;** of which one[4] runs horizontally backwards, forming the outer margin of the articular cavity, whilst the other[5] turns inwards and forms the anterior border of that cavity. **tubercle for the external lateral ligament.** At the point of division is a slight tubercle,[6] which gives attachment to the external lateral ligament of the lower jaw. **Two roots; anterior,** The anterior root widens, and subsides, becoming concave from without inwards and convex from before backwards, and forms part of the articular surface upon which the lower jawbone moves; in its natural condition it is covered with cartilage. **posterior.** The other root, which is continued horizontally backwards,[7] gradually disappears as it passes over the auditory tube, and marks the separation between the squamous and mastoid portions of the bone. **Glenoid fossa.** The articular or *glenoid fossa* (γληνη, a shallow pit), marked off as here indicated, is elongated from without inwards, and **Fissure of Glaser.** divided into two parts by a fissure[9] (*fissura Glaseri*), which transmits the chorda tympani nerve (sometimes), and the laxator tympani muscle, and lodges the processus gracilis of

* For explanation, see the last note.

the malleus. The part before the fissure is smooth, and articulates with the lower jaw; the remainder lodges a process of the parotid gland.

Mastoid part.

B. The *mastoid* part[10] of the bone is rough externally, for the attachment of muscles, and prolonged downwards, forming the mastoid or nipple-shaped process (μαστος, a nipple or teat), from which this division of the bone is named. This process overhangs a groove, fig. 26 [11] (*digastric fossa*), for the attachment of the digastric muscle; close to this is a slight groove[14] (occipital). When viewed at its inner surface, the mastoid part presents a broad and generally a deep sulcus (sulcus sinûs lateralis),[12] which curves forwards and downwards; it here supports part of the lateral sinus. It is usually pierced by a foramen [13] (f. mastoideum), which commences near the posterior border of the bone, and opens into the sinus from the outer surface. The size and position of this hole vary in different instances; it sometimes exists in the one temporal bone and not in the other.

Digastric fossa and occipital groove.

Groove for lateral sinus.

Mastoid foramen.

Petrous part; its shape;

C. The *petrous* part,[15] pars petrosa, named from its hardness (πετρος, a stone), represents a triangular pyramid (pyramis trigona) which projects into the base of the skull forwards and inwards. It contains the organ of hearing, and presents for examination a base, an apex (truncated), three surfaces, and three borders. In the base is situate the orifice of the auditory canal, which is bounded above by the posterior root of the zygoma; inferiorly, and in the greatest part of its circumference, by a curved, uneven lamella (*auditory process*), to which the cartilage of the ear is attached. The canal itself (*meatus auditorius externus*), narrower in the middle than at its extremities, is directed obliquely forwards and inwards, and leads into the tympanum. The *apex* or inner end of the pars petrosa, rough, irregular, and, as it were, truncated, forms part of the foramen lacerum medium, and is pierced by the termination of the carotid canal [18] (canalis caroticus):—this canal commences in the inferior surface of the bone anterior to the jugular fossa, ascends at first perpendicularly, but soon turns horizontally forwards and inwards to the apex, where it ends.

position.

Contains internal ear.

Base, with auditory process.

Meatus auditorius externus.

Apex.

Carotid canal.

Anterior surface;

The *anterior* or *upper surface*[19] of the petrous portion is situate in the middle fossa in the base of the skull, where it looks obliquely upwards and forwards. Towards the apex it is slightly depressed,[20] where it corresponds with

depression for Gasserian ganglion.

the ganglion of the fifth pair of nerves (Gasserian). A narrow groove is seen to run obliquely backwards and outwards to a foramen; it lodges a nerve "the large superficial petrosal," a branch of the Vidian; the foramen

Hiatus, and

is named the *hiatus Fallopii*, and leads to the aqueduct of Fallopius. More externally is a small aperture, which gives passage to a nerve named "the external superficial petrosal." Farther back is a rounded eminence indicating the situ-

aqueduct of Fallopius.

ation of the superior semicircular canal. The *aqueduct* of Fallopius just alluded to commences at the internal auditory meatus; it is a small osseous tube lodged in the interior of the bone, and passes in an arched direction, at first outwards and then backwards towards the base of the skull, where it ends in the stylo-mastoid foramen; it transmits the portio dura, and receives, through the hiatus Fallopii, the petrosal nerve and vessels.

Posterior surface.

The *posterior surface* looks obliquely backwards, and forms part of the third or posterior fossa at the base of the skull. In it will be observed a large orifice,[21] leading to a short

Meatus auditorius internus;

canal (*meatus auditorius internus*). The canal is oblique in its direction, having an inclination outwards and backwards. It contains the auditory and facial nerves. Its fundus is

with its cribrous plate.

formed by a thin plate of bone (*lamina cribrosa*), divided into two parts by a crest or ridge; the upper or smaller part is pierced by a foramen which transmits the facial nerve, whilst the lower presents several very small apertures through which the fibrils of the auditory nerve pass. Close behind the meatus is an irregular depression, into which a small process of the dura mater is fixed. About three lines further back than the orifice of the meatus is a narrow

Aqueduct of the vestibule.

fissure,[22] oblique in its direction: it is the termination of the aquæductus vestibuli.

Inferior surface.

On the *inferior surface* of the pars petrosa, which is exceedingly irregular, may be observed, proceeding from within outwards and backwards:—a rough surface [23] giving attachment to the levator palati and tensor tympani muscles, the carotid foramen, the jugular fossa, the vaginal and styloid processes, and lastly, the stylo-mastoid foramen.

Carotid foramen.

The carotid foramen leads into the curved canal (canalis

Jugular fossa enters foramen lacerum, which is divided.

caroticus) already noticed. The *jugular fossa* [24] (fossa bulbi venæ jugularis internæ, "the thimble-like cavity") forms, with a larger depression in the margin of the occipital bone, the "foramen lacerum jugulare." This large foramen has indented margins, corresponding to the three parts into

which, in the recent state, it is divided. At the back of the jugular fossa is a small opening, by which the auricular branch of the vagus nerve enters the bone. In the plate of bone which separates this fossa from the carotid aperture is the opening of a small canal, through which the nerve of Jacobson passes to the tympanum. External to the margin of the jugular fossa is the styloid or pencil-like process,[25] long and tapering, with an inclination downwards and forwards. Its length varies from an inch to an inch and a half; it gives attachment to three muscles and two ligaments. Close before the base of the styloid process is a compressed bony plate,[26] the *vaginal* process (vagina processûs styloidei), the free surface of which looks obliquely forwards. Between the root of the styloid process and the mastoid (and named from its position with regard to them) is the *stylo-mastoid foramen*[27] (f. stylo-mastoideum). It forms the outlet or termination of the aqueduct of Fallopius, and gives exit to the facial nerve.

Canal for Jacobson's nerve.

Styloid process.

Vaginal process.

Stylo-mastoid foramen.

The *superior border* of the pars petrosa is grooved for the petrosal sinus.[28] The *anterior*, which is very short, makes, with the squamous part, an angle at their point of junction, in which is situate the orifice of the Eustachian tube,[29] a canal which leads from the pharynx to the tympanum: above this last, and separated from it by a thin horizontal lamella (*processus cochleariformis*), is another osseous tube, that gives passage to the tensor tympani muscle. The *posterior border* articulates with the occipital bone, and forms with it the foramen lacerum jugulare. About the middle of this edge or border is a minute foramen,[30] the opening of a small canal leading from the cochlea (*aquæductus cochleæ*).

Borders. Petrosal groove.

Eustachian tube.

Processus cochleariformis.

Aqueduct of the cochlea.

Articulations.—The temporal bone articulates with the parietal, malar, inferior maxillary, sphenoid, and occipital bones.

Connection with other bones.

The *ossification* of the temporal bone begins at an early period,—about the time that osseous matter begins to appear in the vertebræ.

Ossification; period of its commencement

It proceeds from several nuclei. These belong to—1. the zygoma and the squamous part; 2. the tympanic bone; 3. the petrous and mastoid parts; 4. the styloid process. The centres of ossification here mentioned are exclusive of those for the internal ear, and the small bones of the tympanum, which will not be referred to in this place.

Several centres,

besides those of the ear parts.

The formation of bone begins with the *zygoma* and the *squamous* part (fig. 27,[a]); and it is not ascertained with

The zygoma

and squamous part. certainty if they are produced from separate nuclei. Béclard speaks of them as seeming to be distinct; but, if they are ever so, they very speedily coalesce.

The tympanic bone The *tympanic* bone soon succeeds the preceding in the commencement of its growth. This little bone forms about three-fourths of a circle; the deficiency being at the upper part (fig. 27[b]). The shape is rather elliptical than circular. It is grooved along the concave surface for the membrane of the tympanum (annulus membranæ tympani); and it remains distinct from the rest of the temporal bone till about the full period of intra-uterine existence, when it becomes joined by the two extremities beneath the roots of the zygoma.

lodges tympanic membrane.

Fig. 27.*

The petrous and mastoid parts. The *petrous* and *mastoid* parts (fig. 27[c]) originate from the same centre, and the ossification of the latter is to be regarded as a continuation backwards from that of the former. The mastoid process is also in some instances found to have one or even more independent nuclei.†

The part of the temporal bone which is latest in its ossification is the *styloid process*, which remains a separate piece for a considerable time; in some cases it is never united to the rest of the bone. This process varies very much in the length to which it grows; it is sometimes found to reach even to the os hyoides, instead of being connected to that bone by a ligament of some length.

The styloid process late in its growth and in its junction.

Condition of the bone at birth. At birth the temporal bone consists of three pieces, viz. the squamous and zygomatic; the petrous and mastoid; and the tympanic. These pieces soon unite, and the place of junction between the petrous and squamous parts is, for some extent, permanently marked by a sort of suture.

* A temporal bone of the right side, consisting of three separate pieces. *a*. The squamous part and zygoma. *b*. The tympanic bone. *c*. The petrous and mastoid part. The letter *c* is placed on the mastoid end. The remainder of this piece is, in the natural state, covered by the other divisions of the bone; part of it is in the inner wall of the tympanum.

† Kerckringius, "Ostogenia Fœtuum," Tab. 35, 36.

Partial union is sometimes found to have taken place at the usual period of birth.

Afterwards the bone undergoes several changes. The most considerable are the following :—From the tympanic piece bone extends outwards, so as to form the lower part of the auditory canal; at the bottom of this the membrane of the tympanum is placed, instead of being on a level with the surface of the skull, as it is before this change has taken place in the bone. The glenoid fossa becomes much deeper. The surface of the petrous part, previously irregular, is filled up, so to say, and becomes more uniform. And the mastoid part enlarges, and is rendered prominent by the formation of cells in its interior. Changes afterwards.

THE SPHENOID BONE.

The sphenoid, a single bone (figs. 28, 29), is placed transversely at the base of the skull; it enters into the formation of the cavity of the skull, of both orbits, of the nose, and may be said to contribute in a small degree to the hard palate. It is articulated with all the bones of the cranium and several of those of the face, between which it is inserted somewhat like a wedge; whence its name (σφην, a wedge; ειδος, like). The form has been The sphenoid bone; its extensive connections. Form.

Fig. 28.*

* Explanation of figures 28 and 29 :—In the former the sphenoid bone is viewed from above; in the latter it is seen in front. 1. Sella Turcica. 2. The outer part of the body. 3. Groove for the carotid artery. 4. is placed above the left posterior clinoid process. 5. The rostrum. 6. A groove which forms part of the pterygo-palatine canal. 7. points to a sphenoidal sinus. 8. A sphenoidal spongy bone. 9. Basilar surface. 10. One of the great wings. 11. Its orbital surface. 12. Its upper surface. 13. Its external surface. 14. is intended to mark the ridge by which the external surface is divided into a temporal and a zygomatic part. 15. One of the small wings. 16. Ethmoid spine. 17. Anterior clinoid process. 18. Internal pterygoid process. 19. Its hamulus. 20. External pterygoid process. 21. Fissure between the pterygoid processes. 22. Olivary process. 23. The spine. 24. Sphenoidal fissure. 25. Optic foramen. 26. Foramen rotundum. 27. Foramen ovale. 28. Foramen spinosum. 29. Pterygoid foramen —the opening of the Vidian canal.

likened to that of a bat with its wings extended, and the comparison is not very far-fetched, particularly if the ethmoid bone remains attached, as often happens. Like other irregular bones, it may be divided into body and processes.

Division into parts.

To put it in position.

To place this bone in its proper position, so as to perceive clearly the relations of its different parts, observe that it has two thick processes somewhat like legs. Hold it so that these shall project downwards, as if from beneath the body and wings, and let those surfaces of the processes which are hollowed out look backwards.

The body; its upper surface.

Of the body or central part of the bone.—To give precision to its description we say that it presents six aspects or surfaces, each of which looks in a different direction and has distinct relations;—The *superior surface*, which forms part of the basis of the skull, is of limited extent, yet it is hollowed into a deep pit,[1] which lodges the pituitary body: hence this excavation is called *pituitary fossa*, and sometimes "sella Turcica," from some resemblance to a Turkish saddle (ephippium). On each side of the fossa, the surface is depressed,[2] and corresponds with the cavernous sinus; farther back, also on each side, is a superficial groove,[3] directed from behind forwards, which marks the course of the internal carotid artery. Before the fossa is a slightly raised portion of the bone (processus olivaris),[22] on a level with the optic foramina, on which rests the commissure of the optic nerves. Behind it is a prominent ascending lamella, of a square form, and sloping backwards, so as to be continuous with the basilar groove of the occipital bone: the corners of this lamella project over the fossa, and are called the *posterior clinoid processes*[4] (κλινη, a bed).

Sella Turcica.

Posterior clinoid processes.

Fig. 29.*

The *inferior surface* of the body is the narrow interval between the pterygoid processes; it is intersected by a prominent spine (fig. 29,[5]), called the rostrum or azygos process, which dips downwards to join the vomer. At each

Lower surface.

Rostrum.

* For explanation, see foot note, page 51.

side is a small and slightly everted lamella (projecting from the base of the pterygoid process), which articulates with the margin of the vomer. Farther out is a small groove,[6] which contributes with the palate bone to form the *pterygo-palatine canal.* and root of pterygoid process.

The *anterior surface* is very irregular, and presents the openings of two deep sinuses,[7] into which the bone is hollowed : these *sinuses* (*sphenoidal*) do not exist in young children : in the adult, in whom they are of considerable size, they are separated by a thin partition (*septum sphenoidale*), which is continuous inferiorly with the rostrum, and in front projecting as a crest (*crista s. spina sphenoidalis*) it articulates with the central lamella of the ethmoid bone. The sinuses are covered in chiefly by two thin osseous plates,[8] the *sphenoidal spongy bones,* but are not altogether closed by these, for a circular aperture is left in front, by which they communicate with the posterior part of the nose. Anterior surface. Sinuses; their septum. Spongy bones.

The *posterior surface* (fig. 28,[9]) is flat, and united with the basilar process of the occipital bone,—in early life by cartilage, but in adult age by osseous matter. Posterior and

The lateral surfaces are continuous with the great wings, which branch out from them. lateral surfaces.

Of the processes.—The principal processes are, the great wings, the small wings, and the pterygoid processes ; the minor ones are the ethmoid spine, processus olivaris, clinoid processes, the rostrum, and the hamular and spinous processes. The processes.

The *great wings* [10] (alæ majores) project outwards and upwards, from the sides of the body of the bone, and are so formed as to present each three surfaces, looking in different directions. One *anterior* (*orbital*) [11] is somewhat square, smooth, inclined obliquely forwards, and forms part of the outer wall of the orbit. The second [12] (*superior* or *cerebral*), of much greater extent, is elongated from behind forwards, and concave, and constructs part of the middle fossa of the base of the skull, which supports the middle lobe of the brain. The third [13] (*external* or *temporo-zygomatic*), looking outwards and forming part of the side of the cranium, is elongated from above downwards and slightly hollowed : this surface, taken as a whole from the top of the wing down to the root of the pterygoid process, presents two parts different in size, divided by a ridge or crest.[14] The upper and longer division is placed in the temporal fossa, and the inferior or smaller one enters into the zygomatic fossa. The great wings. The three surfaces of each, viz., orbital, cerebral, and temporo-zygomatic.

The small wings; in cavity of skull and orbit.

The *small wings* [15] (alæ minores), called also wings of Ingrassias, are triangular in form, horizontal in direction, and extended forwards and outwards, on a level with the upper surface of the body—its fore part. Their upper surface, plain and flat, supports part of the anterior cerebral lobes, the inferior one overhangs the back of the orbit and its sphenoidal fissure. The anterior border, sharp, thin, and rough, articulates in the greater part of its extent with the orbital plate of the frontal bone; and internally, at the middle line, where the bases of the two processes are united, there is a slight angular process [16] (*ethmoidal spine*), which articulates with the cribriform lamella of the ethmoid bone. The posterior border, rounded and smooth, is free and unattached, and corresponds with the fissure (fissura Sylvii) which separates the anterior from the middle lobe of the brain. The external and the anterior ends of these wings are sharp aud pointed, whilst posteriorly they terminate in two blunt tapering productions (the anterior clinoid processes) [17] which incline obliquely backwards, towards the pituitary fossa, and overlay the cavernous sinuses and the carotid arteries. Each is perforated at the base by a round foramen (*optic*), which transmits the optic nerve and the ophthalmic artery.

Ethmoid spine.

Anterior clinoid process.

Optic foramen.

Pterygoid processes, external and internal;

The *pterygoid processes* are seen at the inferior surface of the bone, from which they project downwards like legs rather than wings, though the name given to them would indicate the reverse (πτερυξ, a wing). Each of these consists of two narrow plates (*pterygoid lamellæ*), united at an angle in front, and diverging behind, so as to form a deep hollow (*pterygoid fossa*). The internal plate,[18] longer and narrower than the external, is prolonged into a slender cylindrical process,[19] named, from its crooked form, the hook-like or *hamular process*, round which plays the tendon of the tensor palati muscle. The external lamella [20] looks outwards, and somewhat forwards, bounding the zygomatic fossa, and projects farther backwards than the other plate. At the root of the internal lamella is situate a slight depression (*fossa navicularis*), which gives attachment to the tensor palati muscle. In the groove or fossa between the two plates, arises the internal pterygoid muscle. The groove is incomplete at its lower part when the sphenoid bone is examined by itself, for an angular interstice [21] exists between the pterygoid lamellæ; but this is filled up by a part of the pyramidal process of the

their differences.

Fossa navicularis.

Pterygoid fossa.

palate bone, which is inserted between the margins of the bony plates.

The *ethmoid spine*, already noticed, is a very small angular plate,[16] which projects forwards in the middle line, on a level with the upper surface of the smaller wings, and articulates with the cribriform lamella of the ethmoid bone. Ethmoid spine.

The *processus olivaris* is a slight elevation on the upper surface,[22] on a level with the optic foramina, which supports the commissure of the optic nerves. Olivary process.

The *clinoid processes* are two pair, one [17] before, the other[4] behind the pituitary fossa; therefore called anterior and posterior. A spiculum of bone often passes from the anterior to the posterior clinoid process at one or both sides. And occasionally another piece passes from this spiculum to the body of the bone; this piece is called the *middle clinoid process.* Clinoid processes.

The *rostrum* is the prominent angular ridge,[5] which projects downwards from the under or guttural surface of the bone, dividing it into two parts. Rostrum.

The *hamular process*[19] projects from the termination of the internal pterygoid plate; it is thin, constricted, and curved, in the greater part of its extent, but ends in a small blunted tubercle. Hamulus.

The *spinous processes*[23] are placed at the posterior and pointed terminations of the great wings, from which they project downwards about two lines. The spine.

Fissures and foramina.—Each lateral half of the bone presents a fissure, four foramina, and a canal. The fissure [24] (*fissura sphenoidalis*), triangular and elongated, is placed between the smaller and greater wings, and opens into the orbit (hence sometimes named foramen lacerum orbitale); it transmits the third, the fourth, and the sixth nerves, the ophthalmic branch of the fifth nerve, and the ophthalmic vein. This fissure is separated at its base from the foramen opticum by a narrow plate of bone, which passes from the under surface of the anterior clinoid process (at its root) obliquely down to the body of the sphenoid bone. Of the foramina,—the *optic foramen*[25] inclines outwards and forwards on a level with the fore part of the body of the bone; it transmits the optic nerve and the ophthalmic artery. Farther back and on a lower plane, inasmuch as it is situate in the great wing, is a round aperture,[26] leading forwards; it is the *foramen rotundum*, which transmits the superior maxillary branch of the fifth pair of nerves. A little farther back and Sphenoidal fissure. Foramina, optic; rotundum;

more external is a large foramen[27] of an oval form, hence called *foramen ovale;* it gives passage to the inferior maxillary nerve. Near the posterior angle of the ala is the *foramen spinosum*[28]; it is very small, and transmits the middle meningeal artery. The root, or base, of each internal pterygoid process is pierced by a circular foramen (fig. 29[29]), more properly a canal (*pterygoid, Vidian*), extending horizontally from before backwards, slightly expanded before, narrowed behind, and giving passage to a branch of a nerve (Vidian) from Meckel's ganglion, with its accompanying vessels.

ovale; spinosum. Pterygoid or Vidian canal.

Connections with other bones.

Articulations.—The body of the sphenoid bone articulates posteriorly with the basilar process of the occipital; anteriorly with the ethmoid, and with the orbital processes of the frontal by the smaller and greater alæ. By the great ala it joins the anterior inferior angle of the parietal, and the squamous portion of the temporal; and by the spinous process it fits into the angle between the petrous and squamous portions of the last bone. With the vomer it articulates by the rostrum; with the malar bone by means of the external border of the orbital plate, and with the palate bone by the pterygoid process, and body;—in all, twelve bones.

Sphenoidal spongy bones; situation; form; bound sinuses.

The *sphenoidal spongy bones* (cornua sphenoidalia, cornets sphénoïdaux, Bertin), two in number, are situate on the lower and anterior aspect of the body of the sphenoid, in contact with the rostrum, and may be recognised as separate pieces till about the fifteenth year of age. Each bone is irregular in shape, but thickened and pointed behind, and thin and dilated in front, where it bounds the sinus in the body of the sphenoid: the surface towards the sinus is concave, and that towards the nasal cavity convex.

Articulations with other bones.

Articulations.—In front with the ethmoid,—the aperture leading from the sphenoidal cell to the nose being between the two bones, or only in the spongy bone; behind, its point is received under the vomer and the ridge at the root of the pterygoid process; externally it unites with the palate bone, and internally it is applied to the rostrum of the sphenoid.

Ossification; time of its beginning. The bone divided into two parts.

The ossification of the sphenoid bone begins soon after it has commenced in the occipital. As this bone is developed from many centres, and some arrangement is necessary for the sake of clearness, it will be considered as divisible into a posterior and an anterior part. Each will be noticed separately.

1.—The *posterior sphenoidal division* includes the great wings, the pterygoid processes of both sides, and the **Posterior sphenoid.**

Fig. 30.*

interposed part of the body. The first nuclei for this part (they are the first that appear in the bone) are deposited in the great wings, one on each side, close to the foramen rotundum, and from this point the ossification spreads outwards into the wing, and downwards into the external pterygoid process (fig. 30, A, B, C,$^{1\,1'}$). **Its lateral pieces.**

The internal pterygoid processes are formed separately, each from a distinct centre (C^4), and they unite with the external soon after the middle of fœtal life. **Internal pterygoid process.**

* A. The sphenoid bone of a fœtus, aged about three months, is seen from above. The great wings are ossified; the body has two round granules of bone beneath the sella Turcica, and the rest of it is cartilaginous. In the small wings, which are formed from a single centre, the ossification has encircled the optic foramen, and a small suture is distinguishable at its posterior and inner side. The internal pterygoid processes are still separate (C^4) in the preparation from which the drawing was made. B. This figure is copied from Meckel ("Archiv." B. 1, Taf. vi. F. 23). It is stated to be from a fœtus at the middle of the sixth month. The two granules for the body are united, and a trace of their union is observable in the notch in front. The lateral projections of the body (^{5}) are separate pieces. C. is a sketch of the back part of the preparation drawn in A. The internal pterygoid process, which was united only by cartilage to the rest of the bone, has been drawn aside. D. This figure represents the sphenoid at the usual period of birth. The great wings are separate. The anterior sphenoid is joined to the body.

1. The great wings. 2. The small wings. 2*. Additional nuclei for the small wings. 3. The body. 4. The internal pterygoid process. 5. The lateral processes of the body.

Its middle or body.

For the formation of this part of the body two rounded granules are placed side by side in the cartilage beneath the sella Turcica (A^3). These, enlarging, unite about the fourth month into a single piece, which is elongated transversely and notched in the middle (B^3). This piece subsequently presents on each side a projection, which Meckel describes and figures as an independent formation (B^5).

Separate at birth.

The parts here described remain separate one from another during the whole of fœtal life, with the exception of the internal pterygoid processes, the time of whose junction with the external has been mentioned.

Anterior sphenoid;

2.—The *anterior sphenoidal division* includes the small wings, with the intermediate fore part of the body of the bone. Its growth commences at an early period, soon after ossification has first showed itself in the bone.

its lateral pieces;

Its first nucleus appears in the small wing, at the outer margin of the optic foramen, and from this point the deposit of bone extends outwards in that wing and around the foramen (A^2). There is frequently another granule placed on the inner side of the foramen (B^2*).

its middle.

The centre of this division either results from the union of the lateral pieces just referred to, or is the product of an independent growth.

Sphenoidal crest.

The sphenoidal crest is perhaps generally produced by extension of the ossification of the middle of the anterior part, and therefore—according to the manner in which the middle is formed—proceeds either from the lateral pieces or from the central one. It is however, not unfrequently, altogether independent in its formation.

The condition of the whole bone at birth.

Some time before the end of fœtal life, the parts of the anterior sphenoid are joined together, and they unite with the centre of the posterior division. So that at birth the sphenoid consists of three large pieces, viz.: 1. The great wing and the pterygoid processes of one side; 2. the same parts of the opposite side; 3. all the anterior division of the bone joined with the central part of the posterior division, so as to form a single piece (fig. 30, D).

Completion of the bone.

In the course of the first year after birth the great wings and the body are no longer separable. About the age of puberty the spongy bones are joined to the sphenoid; they subsequently are connected to the ethmoid, and in consequence of this union they are often broken during the separation of the bones of the adult skull. Lastly, the sphenoid unites with the occipital bone.—See page 39.

Sphenoidal spongy bones; appearance; completion.

The *sphenoidal spongy* bones begin to appear about the end of the third year (Bertin*), as thin osseous plates. Increasing in size, they are prolonged in front of the body of the sphenoid, and include with the hollow of that bone the space named sinus. From the tenth to the twelfth year they commonly begin to join the sphenoid, but this union may be deferred till the fifteenth year; by the twentieth year they are completely united with the contiguous bones.

ETHMOID BONE.

Ethmoid bone; its position, its lightness: the bony matter, thin and papyraceous.

The *ethmoid*, or sieve-like bone (fig. 31; ηθμος, a sieve; ειδος, form; os ethmoides), is common to the cranium, the orbits, and the nasal fossæ. Placed at the fore part of the base of the skull, from which it projects downwards, it is inserted between the orbital plates of the frontal bone, lying behind the nasal and superior maxillary bones, before the sphenoid, and above the vomer. It is exceedingly light and thin, considering its size, and seems at first but a collection of irregular cells, enclosed between plates of bone as thin as paper. It is of a cuboid figure, symmetrical, and composed of two lateral masses, between which is interposed a central vertical plate; and, for the purpose of description, it may be divided into a median and lateral parts.

Fig. 31.†

Division of it.

To find its natural position.

To place the bone in its proper position, observe that its upper surface is the one which is pierced by many holes, and from which arises a smooth angular process like a cock's comb; and that the short border of this process looks forwards.

Of what median part consists.

Median part.—The central part of the bone is flat, and projects above and below a porous or cribriform plate that connects it with the lateral masses: the smaller part above

* M. Bertin has never found these bones in the fœtus.—Mém. de l'Acad. Roy. des Sciences for the year 1744.

† The ethmoid bone seen from the left side. 1. Crista galli. 2. Cribriform plate. 3. Fissure for the foramen cæcum. 4. Perpendicular or central plate. 5. Os planum. 6, 7. Grooves which form parts of the internal orbital foramina. 8. The posterior end of the superior spongy bone. 9. The second spongy bone. 10. Infundibulum.

is named crista galli, and the larger one below, the descending or nasal piece.

The cribriform plate.

The sieve-like or *cribriform lamella*[2] (lamella cribrosa) consists of a narrow plate of bone, pierced by a number of holes, from which it derives its name; posteriorly this plate of bone is, for a very little way, even and horizontal, but it then becomes depressed into two grooves beside the crista on the upper surface, which lodge the ganglia of the olfactory nerves. This part of the surface is narrow, elongated from behind forwards, and pierced by numerous foramina, for the transmission of the filaments of the olfactory nerves. The *foramina* in it are of three sorts: those which lie along the middle of each groove are mere holes or perforations which permit the filaments of the nerves, with their membranous investments, to pass to the roof of the nares; the internal and external sets are larger, and are the orifices of small canals, which are grooved in the bone, and subdivide as they descend on the central and lateral parts of the nose. Towards the fore part of the cribriform plate, is a small fissure at each side of the crista galli, close to its base; and external to this is a special foramen which transmits the nasal filament of the ophthalmic nerve. At the posterior margin of this surface, and in the middle line, is a slight notch, which receives the ethmoid spine of the sphenoid bone.

Its foramina for the olfactory nerves; their varieties.

Aperture for nasal nerve.

Crista galli: position, and form.

The *crista galli* is a firm triangular process, which projects in the middle line from the fore part of the upper surface of the cribriform plate, and has been named from some resemblance to a cock's comb. The surface of the crista is smooth and compact. The base is horizontal, and on a level with the cribriform piece, below which it is continuous with the perpendicular lamella forming the septum narium. The posterior border of this process is long, and slopes backwards; but the anterior is short, and nearly perpendicular, and at its junction with the base two small bony masses sometimes project forwards, leaving between them a fissure which forms part of the "foramen cæcum," placed in the middle line at the junction of this bone with the frontal. The crista galli is usually perpendicular, but occasionally inclines to one side; it is sometimes bulged a little at the sides, and is then found to enclose a small sinus; it gives attachment to the falx cerebri, which in a manner embraces it.

Foramen cæcum.

The descending or *nasal* piece (lamella nasalis), called also

the perpendicular or central plate, though it frequently inclines to one side, forms a considerable part of the septum nasi (fig. 43,[2]). It is continuous above with the base of the crista galli, as already stated; below, it articulates with the vomer and the triangular cartilage of the nose; its anterior margin joins by the upper part with the nasal process of the frontal bone, and lower down supports the ossa nasi; the posterior margin articulates with the septum sphenoidale. This plate presents a number of grooves and minute canals, leading from the foramina of the cribriform lamella, for the transmission of the olfactory nerves.

The central plate is part of the nasal septum;

its grooves and canals.

Lateral masses.—The external surface of each of these is formed by a thin, smooth, and nearly vertical plate of bone, (fig. 31,[5]; *lamella plana, os planum*), which closes in the ethmoidal cells, and forms a considerable part of the inner wall of the orbit: it articulates above with the orbital plate of the frontal bone; below, with the superior maxilla and palate bone; in front, with the os unguis; and behind, with the sphenoid. At its anterior and posterior margins the ethmoidal cells are open when the bone is detached from its connections: in the former situation they are closed by the os unguis; in the latter, by the sphenoidal spongy bone. In its upper margin are two grooves,[6 7] which are converted into foramina by similar indentations in the frontal bone when this is in place, and so form the internal orbital foramina (*foramen orbitarium internum, anterius et posterius*).

The lateral masses. External surface (os planum), has these connections.

Grooves to form foramina with frontal.

The inner surface of each lateral mass (fig. 42) constructs part of the external wall of the nasal fossa of its own side, and is formed by a thin osseous plate, which is connected above with the cribriform lamella from which it hangs down, and ends below in a free margin, which is a little convoluted, and represents the middle spongy bone. At its upper and fore part is a square, flat, but rough surface, which is pierced by a number of grooves leading from the foramina of the cribriform portion; posteriorly are placed two thin and also rough osseous plates, curved a little, so as to represent small bivalve shells, from which circumstance they are called *ethmoidal turbinate* bones; but from their texture, being cellular and porous on the surface, they are also named *spongy* bones. Of these, the first or upper one (fig. 42,[5]), (concha superior), which is also placed farther back, is very small; by the curve or coil which it makes, it arches over, and bounds a groove or channel (*meatus naris superior*): this is of small extent from before backwards, not being more than half

The internal surface.

Two spongy bones;

upper, and superior meatus naris;

that of the ethmoid bone; communicating with it are the posterior ethmoidal cells. Still lower down is another osseous lamella (fig. 42,[7]), thin, rough, and convoluted, which is the second ethmoidal spongy or turbinate bone. Its lower margin is more rough and prominent than that of the upper bone, and its extent from before backwards nearly double. Beneath this is a groove or channel, which it overhangs so as to form the second *meatus naris*. Occasionally there is a still smaller and higher convoluted bone, with its corresponding passage or meatus beneath it.

lower, and middle meatus naris:

may be a third.

Canals for the olfactory nerve.

The surface of these spongy bones is studded over with holes, which are the orifices of canals lodged in their substance. These (the canals) lead from the foramina in the cribriform plate, and they vary in length, some reaching only a very short way, while others extend to the lower margin of the bones. Their direction is nearly vertical, with, in most instances, a slight inclination backwards, and they conduct the branches of the olfactory nerve to the lining membrane of the nasal fossa at different points.

Grooves for other nerves.

There are also generally, if not always, to be found on the second spongy bone—on the posterior margin, and for a short space in front of it—one or two slight horizontal grooves marking the course of small nervous filaments, which enter through the spheno-palatine foramen.

Ethmoidal cells

The osseous plate here described gives attachment by its outer surface to a number of osseous lamellæ, thin and delicate, which pass across the space between it and the lamella plana, so as to form a number of *cells* (*ethmoidal*). These do not all communicate; they are separated into two sets by a sort of transverse partition, the posterior being small and few in number—from four to five, whilst the anterior, larger and more numerous, communicate with the frontal sinus. The cellule (fig. 31,[10]), which directly communicates with the middle meatus, is prolonged, in a curved direction, upwards and forwards, opening by a small aperture into the anterior ethmoidal cells, and by another, farther on, into the frontal sinus; and, as it is broad below, and tapering above, it assumes somewhat the form of a funnel, and hence is named *infundibulum*.

are posterior and anterior.

Infundibulum.

Borders of the lateral mass.

The superior border of each lateral mass presents some open cells, which are closed by the orbital part of the frontal bone; the inferior gives off some irregular pieces, which articulate with the side of the maxillary sinus and the inferior turbinate bone; the anterior also exhibits some

incomplete cells, which are completed by the os unguis and the nasal process of the superior maxillary bone.

Articulations.—The ethmoid articulates with the following bones—the frontal, the sphenoid, and vomer, two nasal, two ossa unguis, two superior maxillary, two palatal, two inferior spongy, and two sphenoidal spongy bones. Connection with other bones.

Ossification.—In the ethmoid bone this process begins about the middle of fœtal life—from the fourth to the fifth month—a period later than belongs to its commencement in any other bone of the cranium. Bone is first visible in the outer sides—the ossa plana,—and soon after becomes apparent in the spongy bones, but the middle part remains cartilaginous till after birth. Ossification; time of its commencement; where first apparent.

At the usual period of birth the ethmoid consists of two parts—the lateral masses,—and these are small and narrow. Condition at birth. Subsequently (in the course of the first year), the middle plate and the lamina cribrosa begin to ossify, and the bone becomes a single piece by the union of the latter to the lateral masses. Pieces join.

The peculiar character of the ethmoid is afterwards gradually developed by the unfolding, as it were, of its substance, and the increase in the size of its cells. Completion of the bone.

OSSA TRIQUETRA.

Supernumerary or unusual bones [a] are not unfrequently found in skulls. From their form, which is variable, they are called sometimes triquetra, at others, triangularia; or ossa Wormii, from Wormius, a learned Danish professor, who is said to have given the first detailed description of them. Ossa Wormiana. They are osseous plates, with serrated margins, inserted, as it were, between two cranial bones (ossa intercalaria, epactalia), and appearing like islets placed in the sutures. Their most ordinary position is in the lambdoid suture, next in the sagittal, seldom if ever in the coronal, never in the squamous. Their most frequent position. The superior angle of the occipital bone sometimes occurs as an accessory piece; so does the anterior inferior angle of the parietal. They are not found before the sixth or eighth month after birth; and whatever varieties of size and appearance they may present, the principle of their formation is the same in all cases. How formed. As the broad bones grow by successive deposits, extending from their central points towards the margins, whenever the natural process is retarded or interrupted, the mode of

osseous deposition takes a new direction. A new centre is established between the margins of the bones, and therefore in the situation of the suture ; from this centre bony material extends, until it comes into contact with the margins of the contiguous bones, with which it becomes united in the usual way by denticulation.

BONES OF THE FACE.

Facial bones form hæmal arches of head segments.

These, as above stated, page 34, are fourteen in number. They are situate in front of the cranial cavity, and most of them form the anterior visceral arches, those named hæmal (p. 3), of the head segments. The more or less perfect loops constructed by them will answer to the arches of the ribs, &c., in the trunk.

THE SUPERIOR MAXILLARY BONE.

Superior maxilla; how it is divided.

This bone (fig. 32; maxilla superior) is very irregular. It presents an external convex surface, corresponding with the anterior and lateral parts of the face; another, internal, of considerable extent, entering into the nasal cavity; one, superior, smooth, and inclined outwards, enters the floor of the orbit, and is surmounted internally by a triangular process, which forms the side of the nose; lastly, a surface which projects horizontally inwards as part of the arch of the palate. The external surface is bounded inferiorly by a thick, dependent border (alveolar), for the lodgment of the teeth; to this, as to a common point of union, all the other parts of the bone may be referred.

Fig. 32.*

To find natural position.

The natural position of the bone will be obtained by putting outwards the convex smooth surface, upwards

* The outer surface of the left superior maxilla:—1. The middle of the alveolar border. 2. The side of the anterior nares. 3. The nasal process. 4. Groove for the nasal duct. 5. The malar process. 6. Canine fossa. 7. Infra-orbital foramen. 8. Myrtiform fossa. 9. The tuberosity. 10. The orbital plate. 11. A ridge, terminating anteriorly at 12, the anterior nasal spine.

the orbital part, and forwards the excavated border or the smallest teeth.

The *alveolar border*,[1] thick, semicircular, convex externally, concave internally, is pierced along its margin by a number of deep pits (*alveoli*), into which the teeth are inserted. The pits or sockets vary in form and depth, conforming in these particulars to the roots of the teeth which they receive.

Alveolar border contains teeth.

The *outer surface* ascends from the lower border to the margin of the orbit, presenting some depressions and elevations. At its fore part it is interrupted and excavated so as to present a deeply concave margin,[2] which, with a similar one in the corresponding bone, forms the anterior nares : this excavation is surmounted by a process[3] (*ascending* or *nasal*), prolonged as far as the frontal bone, with which it articulates. The part of the external surface a little above the molar teeth, is elevated into a rough projection,[5] (*malar process, eminence, tuberosity*,) for its articulation with the malar bone. Anterior and inferior to this is observed a fossa,[6] (*fossa canina*,) which gives attachment to the levator anguli oris. Between this fossa and the margin of the orbit is the *infra-orbital foramen*,[7] which transmits the superior maxillary nerve and its vessels. A little above the sockets of the incisor teeth is a slight depression,[8] (*superior incisor* or *myrtiform fossa*,) which gives attachment to the depressor muscle of the ala of the nose. Behind the malar tuberosity the surface is slightly excavated, and forms part of the zygomatic fossa ; towards the posterior border it is plain, and limits on one side the pterygo-maxillary fissure ; and at its junction with the orbital plate, it is rounded off and leads to the entrance of the infra-orbital canal. It terminates by a slight *tuberosity*,[9] (tuber maxillare,) which projects behind the last molar tooth, and is perforated by a number of foramina, which transmit the superior dental nerves and vessels. The inner surface of its posterior border is rough, for its attachment to the tuberosity of the palate bone, and presents also a slight groove, contributing to the formation of the *posterior palatine canal*, which transmits the descending palatine vessels and nerve.

Outer surface; nasal excavation and process. Malar eminence. Canine fossa. Infra-orbital foramen. Incisor fossa. The tuberosity and foramina. Palatine canal.

The external surface of the *nasal process*, slightly grooved, gives attachment to the orbicularis palpebrarum muscle and the levator labii superioris alæque nasi. The internal, or nasal surface, somewhat concave, presents a ridge, running from before backwards, which articulates with the inferior

Nasal process; its surfaces

spongy bone ; above this is a depression corresponding with the middle meatus of the nose, and, towards the summit, a rough surface, which closes in the anterior ethmoidal cells. The anterior border is rough, for its articulation with the nasal bone ; the posterior presents a well-marked groove,[4] running from above downwards and a little backwards with a slight curve, and which is completed into a canal for the lachrymal sac, by a similar hollow in the os unguis.

and borders. *Lachrymal groove.*

The orbital plate,

From the upper border of the external surface of the bone, the *orbital plate* [10] projects backwards, forming the floor of the orbit ; its surface is smooth, being merely interrupted by the groove which leads to the infra-orbital canal ; and at its inner and fore part, near the lachrymal groove, is a minute depression, which gives origin to the inferior oblique muscle of the eye. The *infra-orbital canal* commences behind on the surface of the orbital plate as a groove ; becoming deeper in front and being changed into a complete canal, it opens on the anterior surface of the bone at the infra-orbital foramen, some distance below the margin of the orbit. It gives passage to a large nerve and its vessels. In the interior of the bone a small canal leads downwards from the larger one, and conducts a nerve and vessels (anterior dental) to the front teeth.

and infra-orbital canal.

Palate plate.

The horizontal or *palate* plate of the bone projects inwards, forming the roof of the mouth and the floor of the naris. Its nasal surface is concave from side to side, and smooth ; externally it is continuous with the body of the bone, internally it presents a rough surface, which is articulated with the corresponding bone, and surmounted by a ridge,[11] which completes the septum narium by articulating with the vomer and nasal cartilage. In front it is prolonged a little, so as to form a small process[12] (*anterior nasal spine*) ; beside this is the *incisor foramen*, leading into the anterior palatine fossa. The inferior surface of the palate plate, which overhangs the mouth, is arched and rough ; and among the prominences of the surface is a slight groove for a large nerve and vessels, which reach the palate through the posterior palatine canal.

The spine. *Incisor foramen.*

Fig. 33.

Anterior palatine fossa.

On examining with attention the large canal or fossa in the skull, named the *anterior palatine*, fig. 33, it will be found

to contain four openings—two placed laterally,[1 2] and two in the middle, the one[4] before the other.[3] The two former are described as the foramina of Steno* (of Stenonis more properly) in many of the older anatomical works. They are mentioned above as the "incisor" foramina: they blend below in the fossa, but are separate above, and open, one in the floor of each nostril. The others, which are oftentimes very indistinct, were first brought under notice by Scarpa; they are placed in the intermaxillary suture, so that both maxillary bones contribute to form each of them, and are smaller than the preceding pair, from which they are separated by a very thin partition. When they are well marked, the lower orifice of the posterior one is larger than that of the anterior. It is through these median smaller canals (of Scarpa) that the naso-palatine nerves pass,—the nerve of the right side occupying the posterior one, and the nerve of the left side, the anterior.† The openings into it; two incisor foramina, and two canals of Scarpa, anterior and posterior.

The body of the bone is hollowed into a large cavity, *antrum maxillare*, or *Highmori*, which in the fresh state is lined by mucous membrane, and communicates with the middle meatus of the nose. Its orifice appears of great size in the dried bone detached from its connections, but it is considerably diminished when the contiguous bones, viz. the ethmoid, the inferior turbinate, and the palatal, are in their natural position. The antrum, or maxillary sinus.

Articulations.—With the corresponding bone; with the frontal, by its nasal process; also with the ethmoid and os nasi; with the palate bone; with the malar, by the malar eminence; with the os unguis, the vomer, the inferior spongy bone, and the nasal cartilage. Connection with other bones.

The *ossification* of the upper maxillary bone begins at a very early period,—immediately after the lower maxilla and the clavicle, and before the vertebræ. The facts hitherto ascertained with respect to its earliest condition are not adequate to determine the number of nuclei from which Ossification. Number of nuclei undetermined.

* The name is usually thus written in English books; but it should be mentioned, that the real name was "Stenson," and of this the ordinary Latin version was "Stenonis."—See, among others, Haller, "Elem. Physiol." t. i. p. 353.—Blumenbach, "Introduct. in Histor. Medicinæ Litt." p. 253.

† The median canals have not unfrequently a different disposition. Thus, *a.* They may join and open inferiorly by a single common orifice. *b.* Either may be wanting. *c.* One may be found to open into a lateral (incisor) canal. See Scarpa, "Annotat. Anatom." lib. ii. cap. 5.

this bone is formed, or the manner of its growth. If it is produced from several centres—and to this the balance of evidence inclines—the very early period at which the osseous deposit begins, and the rapidity of its progress, will account for the difficulty of marking the phases of change.

Observation of Béclard, that four pieces exist.

Béclard, whose opportunities of observing the growth of this and most other bones were considerable, states that he has found it to consist of four pieces, viz. 1. A palatal part, including all the palate except the incisor portion. 2. An orbital and malar division, comprising the parts implied by these names. 3. The nasal and facial connected. 4. The incisor piece,—being a small part of the palate behind the incisor teeth, and including in front the posterior margin of the alveolar border. But this anatomist adds, that he had not the means of determining where the several pieces unite one to another, and he admits that further observations of the bone at very early periods are necessary to determine the course of its ossification.

Fig. 34.*

Fissures; orbital and incisor.

Taking this bone when a single piece, it presents two fissures, one along the floor of the orbit (fig. 34, A[1]) : the other, (the incisor groove,) marking off a small portion of the palate behind the incisor teeth (B, C[2]). Now, the question arises, are these the limits of ossification proceeding from different centres? There does not appear to be evidence that the first is so, for its presence may be owing

* The superior maxillary bone at early periods :—On the outer side, A, a fissure extends through the orbit and ends at the infra-orbital foramen. B is a view of the inner side of the bone. The incisor fissure reaches upwards through the horizontal plate and some way on the nasal process. C. The alveolar border and palate plate are displayed from below, and the incisor fissure is seen to cross those parts. At the outer side a small portion of the orbital fissure was noticeable in this view of the bone, and it has been represented. 1. The orbital fissure. 2. The incisor groove or fissure.

solely to the construction of the canal over which it is placed. But with regard to the second, there are circumstances which would incline us to expect that the portion of bone it circumscribes would prove to be a distinct growth. The circumstances alluded to are the following: 1. The existence, in some cases of hare-lip, of a detached piece, corresponding in its extent on the palate to the line of this fissure, and including the entire thickness of the alveolus with the incisor teeth. 2. The strictly-defined extent of this piece: it never reaches beyond the line of the fissure—never includes a canine tooth. 3. No similar portion is ever found detached from any other part of the upper, or from the lower maxillary bone. 4. Lastly, may be added the existence of an intermaxillary bone in animals, with which an incisor piece in man would be corresponding.

Is there a separate incisor piece?

Reasons for expecting to find one.

The foregoing facts render it probable that the incisor part is formed separately from the rest of the bone. Still, seeing that, except in cases of malformation, a distinct piece has not hitherto been clearly observed by any anatomist, and that the trace of separation which exists on the palate has never been found to extend to the anterior surface of the alveolus, it cannot be concluded that the part of the bone defined below by the incisor groove is ordinarily formed from a distinct centre of ossification. In the present state of knowledge, therefore, the existence of an incisor bone in the human body at any period, cannot be admitted.

Its existence not proved.

THE MALAR BONE.

Malar bone.

There are two bones named malar (os malæ, malare, jugale, zygomaticum). Each is common to the face and orbit, forming the most prominent point of the side of the former, and the greater part of the outer border of the latter. Its form is quadrangular.

Surfaces; anterior; its foramina.

The facial or anterior surface, pierced by some *foramina* (*malar*) for small nerves and vessels, is convex;—the posterior overlays the zygomatic fossa, and is rough at its fore part for its articulation with the superior maxillary bone. The superior surface, smooth, narrow, and lunated, extending into the orbit, articulates with the frontal, sphenoid, and superior maxillary bones, and contributes generally by a small smooth margin to bound the spheno-maxillary fissure: it is pierced by two or three foramina, and gives passage to a small nerve, which passes outwards through it.

Superior; its foramina

Borders. Zygomatic arch.

The superior border forms the outer margin of the orbit; the inferior is in a line with the zygomatic arch, which it contributes to form; the anterior articulates with the superior maxillary bone; the posterior, curved, gives attachment to the temporal aponeurosis.

Angles; their differences.

The angles of the bone are readily distinguished from each other. They are four in number. In front, the upper one is slender and pointed, and rests on the superior maxillary bone; whilst the lower one is less prominent than the others. Behind, the superior angle is thick, and joins the external angular process of the frontal bone; but the inferior is thin, and supports the zygomatic process of the temporal, the suture between the two bones being often vertical at the lower end.

Connection with other bones.

Articulations.—It articulates with the frontal, superior maxillary, temporal, and sphenoid bones.

Ossification.

Ossification.—It extends from a single ossific point, which appears about the time that the ossification of the vertebræ commences.

THE NASAL BONE.

Nasal bone. Form.

The nasal bones (ossa nasi), situate beneath the frontal bone, and between the ascending processes of the superior maxillary, are small and irregularly quadrilateral, and form what is called the "bridge" of the nose. They are thick and narrow in their upper part, but gradually become wider and thinner lower down.

Surfaces.

The anterior surface of each, concave from above downwards, convex from side to side, presents a minute vascular foramen; the posterior, or nasal, is marked by the passage of a branch of the nasal nerve.

Borders.

The superior border articulates with the frontal bone; the inferior with the nasal cartilage; the external edge with the ascending process of the superior maxillary bone; and the internal with its fellow, supported by the nasal spine of the frontal bone, and the perpendicular plate of the ethmoid.

Growth.

Ossification.—They are developed each from a single osseous centre, which is discernible about the same time as the nuclei in the vertebral column.

OSSA UNGUIS—OSSA LACHRYMALIA.

Os unguis, or lachrymal bone.

These small bones are named "ungual" from a resemblance, if not in form, at least in thinness and size, to a

finger-nail (unguis); they are also called the "lachrymal" bones, from their presenting each a groove, which, with a similar excavation in the nasal process of the superior maxilla, forms the lachrymal canal. Placed at the inner and anterior part of the orbit, the os unguis presents two surfaces and four borders. Its external or orbital surface, plain in the greater part of its extent, is hollowed anteriorly by a groove which runs from above downwards, and contributes, as above stated, to lodge the lachrymal sac: the hinder border of the groove is prolonged forwards below, in the form of a hook or spur (*hamulus lachrymalis*). The inner surface has a slight longitudinal groove about its centre; the part behind that mark is rough, and closes the anterior ethmoidal cells, and the rest corresponds to the middle meatus narium. The superior border is articulated with the orbital process of the frontal bone; the inferior, with the superior maxillary bone; and, where it dips down to form a part of the lachrymal canal, it joins the inferior spongy bone. Anteriorly, it rests on the nasal process of the superior maxillary bone, and posteriorly on the os planum of the ethmoid.

Situation. Surfaces. Groove; its outer edge has a hook. Borders, and articulations

Ossification.—Each os unguis is developed from one osseous centre, which is apparent shortly after the ossification of the vertebræ is begun.

Growth.

THE PALATE BONE.

Each palate bone, figs. 35 and 36, (os palati,) wedged in between the superior maxillary and sphenoid bones, is common to the cavities of the mouth, nose, and orbit. In its form this bone resembles somewhat the letter L, one part being horizontal, the other vertical.

Palate bone, its position.

Fig. 35.*

Division.

The bone of one side may be recognised from that of the other by directing inwards the horizontal part, upwards the vertical, and backwards the projecting lower part.

The horizontal or *palate* plate[1] of the bone, which is nearly square, and forms the back

The horizontal plate.

* Fig. 35 is a view of the left palate bone, seen from behind and slightly on the inner side. In fig. 36 the outer side of the bone is represented. 1. The palate plate. 2. A ridge or crest. 3. The

It separates the nasal fossa from the mouth.

part of the roof of the mouth and of the floor of the naris, articulates anteriorly with the palate plate of the superior maxillary bone. Internally it presents a rough thick border which, rising up into a ridge,[2] joins with its fellow of the opposite side, and with it forms a groove which receives the lower border of the vomer; externally it unites at right angles with the vertical portion of the bone. Posteriorly it presents a thin free border, forming the limit of the hard palate, and giving attachment to the velum or soft palate which projects downwards from it: it is slightly concave, and has at the inner and hinder end a pointed process,[3] (*the palate spine*). The superior surface of this plate is smooth, and forms the back part of the floor of the nasal cavity. The inferior, which forms part of the roof of the mouth, is unequal, and marked by a transverse ridge, into which the tendinous fibres of the circumflexus palati muscle are inserted: externally is a sulcus or an oval foramen, being the inferior termination of the posterior palatine canal, which transmits the large descending palatine nerve and accompanying vessels; and farther back, is another of smaller size, for the middle palatine nerve.

Connection of soft palate.

Palate spine.

Posterior palatine canals.

The tuberosity.

At the junction of the horizontal and vertical portions is situate the thick rough part or *tuberosity*,[4] (*pyramidal process*,) projecting downwards and backwards. This is marked by three vertical grooves; the two lateral ones are rough, and receive the inferior borders of the pterygoid plates of the sphenoid bone; and the middle one,[5] smooth, corresponds with and completes the fossa between the pterygoid plates.

Fig. 36.*

Vertical part.

Surfaces:

inner;

The vertical portion of the bone is flat and thin, and presents two surfaces. The internal one (*nasal*) is divided into two parts by a transverse ridge (crista transversa),[6] which articulates with the inferior spongy bone; the space below the ridge forming part of the inferior meatus, that above it, of the middle meatus. The external surface, rough and unequal, fig. 36, is divided by a vertical groove, which is completed into a canal (*posterior palatine canal*) by the

outer grooved.

spine. 4. The tuberosity. 5. Its smooth part for the pterygoid fossa. 6. Crest for the inferior turbinate bone. 7. Spheno-palatine foramen. 8. The sphenoidal process. 9. The orbital process; and 10, 11, 12, 13, 14, are different surfaces of the orbital process.

* See note above.

maxillary bone. The posterior part of this surface articulates with the rough hinder border and inner surface of the maxillary bone; and the anterior, thin and scaly, with the side of the antrum.

The vertical portion of the palate bone presents at the top a notch,[7] forming the greater part of a foramen, which is completed by the sphenoid bone when the parts are in their natural position. This is called the *spheno-palatine* foramen; and outside it is placed the nervous ganglion of the same name (Meckel's ganglion). This notch divides the upper part of the bone into two processes or heads, an anterior or sphenoidal, and a posterior or orbital.

Divided into two parts above, between which is the spheno-palatine foramen.

The *sphenoidal* process,[8] smaller and not so prominent, presents three surfaces, of which one, internal, looks to the nasal fossa; another, external, forms a small part of the zygomatic fossa; and the third, superior, grooved on its upper aspect, articulates with the vomer and the under surface of the sphenoid bone, and forms the *pterygo-palatine* canal with the groove on the inner pterygoid plate.

Sphenoidal process; three surfaces.

The *orbital* process[9] inclines outwards and forwards, and has five surfaces, two of which are free and three articulated; of the latter,—the internal one, hollowed, rests against the ethmoid bone, and covers some of its cellules; the anterior[11] is flat and articulates with the superior maxillary bone; and the posterior[12] (which is hollow), with the sphenoidal spongy bone, and forms part of the sphenoidal sinus. Of the non-articular surfaces, one superior,[13] smooth and oblique, constructs a small part of the floor of the orbit; the other, external,[14] looks into the zygomatic fossa.

Orbital process; five surfaces.

Articulations.—With the corresponding palate bone; with the superior maxillary, ethmoid, sphenoid, vomer, and the inferior and sphenoidal spongy bones.

Connection with other bones.

Ossification.—The palate bone is formed from a single centre, which is deposited at the angle formed between its parts. From this the ossification spreads in different directions—upwards into the vertical plate, inwards into the horizontal one, and backwards into the pyramidal process. For a considerable time after it has been fully ossified this bone is remarkable for its shortness; the horizontal plate exceeds the vertical one in length in the fœtal skull.

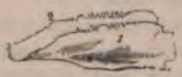
Growth, from one centre.

THE VOMER.

Vomer; surfaces; borders; and connections.

The vomer (fig. 43,[3]), so called from its resemblance to a ploughshare, is flat, irregularly quadrilateral, and placed vertically between the nasal fossæ, presenting two surfaces and four borders. The lateral surfaces form in part the inner walls of the nasal fossæ. The superior border, thick and deeply grooved, receives the rostrum of the sphenoid bone; the margins of the groove expand and are articulated with the palate and sphenoidal spongy bones, and with the small lamella at the root of the pterygoid process. The inferior is received into the fissure formed by the palate plates of the superior maxillary and palate bones. The anterior border, also grooved, presents two portions, into one of which is implanted the descending plate of the ethmoid, and into the other the nasal cartilage. The posterior border, separating the posterior nares, is thin and unattached.

Fig. 37.*



Ossification.

Ossification begins in the vomer about the same time as in the vertebræ. In the early periods the bone consists of two laminæ separated by a considerable interval, except at the lower border where they are joined (fig. 37).

THE INFERIOR TURBINATE BONE.

Inferior spongybone.

Each *inferior turbinate*, or *spongy bone*, is so called from its texture in the latter case, and from some resemblance to the lateral half of an elongated bivalve shell in the former. Situate in the nose, it extends from before backwards, along the nasal fossa, and appears as if appended to the side of the superior maxillary and palate bones. It is slightly convoluted, and presents an external concave surface, which arches over the inferior meatus, and an internal convex surface, projecting into the nasal fossa (fig. 42,[10]). This bone is expanded and thin in front, but pointed behind; and it has not any canals or foramina for the olfactory nerve, like the spongy bones of the ethmoid, but is marked by horizontal branching grooves (in part canals) for other nerves and vessels. Its superior border articulates with the ascending process of the maxillary bone before, with the

Surfaces. Ends. Borders;

* The vomer from the skull of a fœtus. It consists of two plates (1, 2), united below.

palate bone behind, and near the centre, by means of a projecting part, with the os unguis; it presents also a hooked process, which curves downwards and articulates with the side of the antrum. The inferior border is free, thickened and slightly twisted, and dependent. and connections.

Ossification commences about the middle of fœtal life, and from a single point. Growth.

THE INFERIOR MAXILLARY BONE.

The inferior maxilla, fig. 38, (os maxillæ inferius, mandibula,) of considerable size, is the thickest and strongest bone of the face, of which it forms a large portion of the sides and fore part. It is convex in its general outline, and shaped somewhat like a horse-shoe. It is usually considered as divisible into a middle larger portion—its body, and two branches or rami. Inferior maxilla. Its shape. Division into parts.

Fig. 38.*

The *body* is placed horizontally; its external surface is convex, and marked at the middle by a vertical line[2] indicating the original formation of the bone from two lateral parts, and named its *symphysis*. On each side of the symphysis, and just below the incisor teeth, is a superficial depression,[3] (the *incisor fossa*,) which gives origin to the levator menti muscle; and, more externally, a foramen,[4] (*foramen labiale, mentale*,) which transmits the facial branches of the dental nerve and artery. A raised line may be observed to extend obliquely upwards and outwards from near the symphysis to the anterior border of the ramus; it is named the *external oblique* line,[5] and gives attachment to muscles. The *internal surface* of the body of the bone is concave in its general outline, and marked at its centre by a The body. Symphysis. Foramen labiale. External oblique line.

* 1. The body. 2. The symphysis. 3. The incisor fossa. 4. Foramen labiale. 5. The external oblique line. 6. The mylo-hyoid ridge. 7. Ramus of the left side. 8. Inferior dental foramen. 9. Mylo-hyoid groove. 10. The coronoid process. 11. The neck. 12. Condyle. 13. Sigmoid notch.

Union in advanced life.

The several pieces generally remain separate, though they are sometimes found united in old age.

THE CONNECTION OF THE BONES OF THE HEAD ONE WITH ANOTHER.

THE SUTURES.

The sutures of the skull; their number, and division.

The bones of the skull, and those of the face, are joined together by seams or sutures. The cranial sutures are commonly said to be five in number, of which three are termed serrated, the margins of the bones being, in a manner, dovetailed one into another: the remaining two are called squamous, as the bones merely overlap one another, like the scales of fishes. The serrated sutures are, the coronal, the lambdoidal, and the sagittal. These names are obviously ill-chosen; they convey no notion of the position which the sutures occupy in the skull, or of the bones which they connect.

Coronal; why so named; its position; its character at different points.

The *coronal* suture (sutura coronalis) has been so named from being situate where the ancients wore their garlands (coronæ). It connects the frontal with the two parietal bones, and hence it may with more propriety be called "*fronto-parietal.*" It commences at each side about an inch behind the external angular process of the frontal bone, where the anterior inferior angle of the parietal articulates with the great wing of the sphenoid bone. From this point it mounts rather obliquely up towards the vertex, having an inclination backwards. The dentations are better marked at the sides than at the summit of the head, for in the latter situation the suture approaches somewhat the squamous character, to allow the frontal bone to overlay the parietal. A similar change takes place at its lower part or commencement, with this difference, that there the parietal bones are made to overlay the frontal.

Lambdoidal; whence the name; its position: may be interrupted.

The *lambdoid* suture (sutura lambdoidalis) is placed between the occipital and the parietal bones; its form resembles somewhat that of the Greek letter Λ, whence its name has been taken. It begins at each side on a line with the posterior inferior angle of the parietal bone, and thence inclines upwards and forwards to the point at which the two parietal bones are joined by the sagittal suture. It thus represents two sides of a triangle. It is often interrupted by accessory osseous pieces (ossa Wormiana). From its

position and relation this suture may be named "*occipito-parietal.*"

The *sagittal* suture (s. sagittalis—sagitta, an arrow) extends directly backwards, from the middle of the coronal to that of the lambdoid suture, and connects the two parietal bones, from which circumstance it may be called the "inter-parietal" suture: in children, and occasionally in adults, it is prolonged through the frontal bone, even to the root of the nose.

Sagittal; its position; varies in length.

The line of union between the occipital and the temporal bone at each side used to be considered as a continuation of the lambdoid suture, or as an appendix to it, and was accordingly named *additamentum suturæ lambdoidalis.* It may, however, be named *temporo-occipital,* as it connects the mastoid and petrous parts of the temporal bone with the occipital—principally its basilar and condyloid portions. In this suture there are no regular denticulations; in a great part of its extent the margins of the bones are merely in apposition.

Additamentum suturæ lambdoidalis; its position and character.

The *squamous* sutures (suturæ squamosæ) are arched, and mark the junction of the lower borders of the parietal bones with the squamous parts of the temporal, the edges of the bones being so bevelled off as to allow the latter to overlay the former. At the point of junction between the squamous and mastoid parts of the temporal bone, the true squamous suture ceases; but from thence a short suture runs backwards to the lambdoid, connecting the mastoid part of the temporal with the postero-inferior angle of the parietal. This is termed *additamentum suturæ squamosæ*:—both together form the "*temporo-parietal*" suture.

Squamous; position; its additamentum.

The lines of direction of the sutures (particularly the lambdoid and sagittal) are not unfrequently interrupted by additional bones, inserted between those hitherto enumerated. These, from being sometimes of a triangular form, are called *ossa triquetra,* and also *ossa Wormiana.* The sutures present a serrated appearance only on the external surface of the bones; the internal surface, or table as it is called, of each bone being merely in apposition with that of the contiguous bone.

Wormian bones. Character of the serrations.

The cranial bones are joined to those of the face by sutures, which are common to both sets of bones. The *transverse* suture, observable in part at the root of the nose, extends across the orbits, and connects the frontal with the nasal, superior maxillary, ossa unguis, ethmoid, sphenoid, and malar

Sutures connecting the cranium and face;

bones. The *zygomatic* sutures are very short; they are directed obliquely downwards and backwards, and join the zygomatic processes of the temporal with the malar bones. The *ethmoid* suture surrounds the bone of the same name; so does the *sphenoid;* they are necessarily complex in consequence of the many relations of these bones. The connection between the nasal and maxillary bones, though sufficiently marked, has not received a particular name; but that observable between the horizontal part of the latter and the palate bone, may be termed the *palato-maxillary* suture.

and those between the bones of the face.

THE GENERAL CONFORMATION OF THE SKULL.

The skull generally.

After having described, in detail, the separate bones of the skull and face, it becomes necessary to review them collectively. The description of these bones forms the most difficult part of human as well as of comparative osteology, as they are the most complex in the whole skeleton; but a correct knowledge of them is indispensable, in consequence of the many important parts which they serve to sustain and enclose; viz. the cerebral mass, with its nerves and vessels; the organs of sight, hearing, smell, and taste; and parts of those of mastication, of deglutition, and of the voice. To facilitate the description of the numerous eminences, depressions, cavities, and foramina of the skull, anatomists examine successively its external and its internal surfaces.

Its external and internal surfaces.

THE EXTERNAL SURFACE OF THE SKULL.

The external surface divided into five regions.

This surface may be considered as divisible into five regions, three being somewhat of an oval figure, and situate, one superiorly, another at the base, the third in front, including the face; the others comprise the lateral parts, and are somewhat flat and triangular.

Superior region; its bounds.

A. The *superior region* extends from the frontal eminences to the occipital protuberance, and transversely, from one temporal ridge to the other; it thus includes the upper broad part of the frontal, almost all the parietal, and the superior third of the occipital bone, which together form the vaulted part of the skull. It is divided into two symmetrical parts by the sagittal suture, and its continuation when it exists; it presents no aperture or other inequality deserving of particular notice. It is covered by the common integument and occipito-frontalis muscle, on which ramify branches of

the frontal, temporal, occipital, and auricular vessels, as well as branches of nerves from the fifth and portio dura, and also from the occipital nerve.

B. The *inferior region* (fig. 41), also oval in its outline, is the most complex of all, as it includes the entire base of the skull, extending from the incisor teeth to the occipital protuberance, and transversely, from the mastoid process and dental arch on one side, to the corresponding points on the other. It may be considered as divisible into three parts—anterior, middle, and posterior. Inferior region, or base of the skull; its bounds; subdivided into three parts.

1. The *anterior part* of the base corresponds with the extent of the arch of the palate. It is divided into two equal portions by a line,[1] extending from before backwards, and marking the junction of the palate processes of the superior maxillary and palate bones; this is intersected by another,[2] running transversely between the palate and the corresponding maxillary bone. Anteriorly, and in the middle line, is a fossa or canal,[3] (the *anterior palatine*,) which communicates with the nasal cavity by four foramina or short canals (for a description of these, see page 66.). Posteriorly, on each side, and just within the alveolar border, is another foramen,[4] (*posterior palatine*,) for the posterior palatine nerve and vessels. Anterior or palate part. Objects on it.

Fig. 41.*

2. The middle, or guttural part, is bounded at each side by a line extended from the pterygoid process,[5] to the mas- Middle or guttural part, its bounds,

* 1. The longitudinal palatal suture. 2. The transverse palatal suture. 3. The anterior palatine foramen. 4. The lower opening of the posterior palatine canal. 5. The external pterygoid process. 6. The mastoid process. 7. The basilar process. 8. Petrous part of the temporal bone. 9. Foramen lacerum jugulare. 10. Foramen lacerum medium: vel f. l. anterius basis cranii. 11. Foramen ovale. 12. Spinous foramen. 13. Carotid foramen. 14. Septum narium—the vomer. 15. The condyles of the occipital bone. 16. The condyloid fossa. 17. The stylo-mastoid foramen.

toid process,[6] and behind, by a line in front of the foramen magnum, thus including the posterior aperture of the nares, and the central part of the base of the skull. In the centre of this space is situate the basilar process[7] of the occipital bone, marked by slight inequalities for the attachment of muscles, and on each side, towards its posterior boundary, the anterior condyloid foramen, which transmits the ninth nerve. On each side is the pars petrosa[8] of the temporal bone, with the styloid and vaginal processes. More posteriorly is the jugular fossa, which is completed into a foramen[9] (*foramen lacerum jugulare*) by the border of the occipital bone: the margin of this foramen is undulating and exhibits one or two points on each side, according to the number of the subdivisions of the cavity in the recent state. The foramen is generally divided into three compartments by processes of fibrous tissue; through the anterior passes the inferior petrosal vein, through the middle one, the eighth nerve, and through the posterior the jugular vein. Bounded by the apex of the pars petrosa, the side of the basilar process, and the body of the sphenoid bone, is the *foramen lacerum basis cranii*,[10] which is closed by cartilage: across its area, as viewed at its upper or cerebral aspect, runs the internal carotid artery, together with the Vidian nerve; and through it pass some small vessels, especially veins. Between the contiguous margins of the pars petrosa and the great ala of the sphenoid bone is a groove, which leads forwards to the Vidian foramen, and backwards to the cavity of the ear, and lodges the cartilaginous part of the Eustachian tube. The other foramina of this region, taken in their order from within outwards and backwards, are, the foramen ovale,[11] foramen spinosum,[12] foramen caroticum,[13] and foramen stylo-mastoideum.[17]

foramina, &c.

Posterior nares.

In the fore part of this division of the base of the skull is the posterior aperture of the nares, which is divided into two parts by the vomer.[14] It is bounded above by the sphenoid bone and the vomer, below by the palate plates of the ossa palati, and on the sides by the pterygoid processes. Each opening measures about an inch in the vertical direction, and half that extent transversely. Of the two plates which constitute each pterygoid process, the inner one is much the smaller: near its junction with the body of the bone is the scaphoid fossa, for the origin of part of the circumflexus palati; and at its inferior termination is the hamular process, round which the tendon of that muscle is reflected. Between

Pterygoid process, and

the front of the pterygoid process* and the posterior palatine foramen is situate a small opening, which leads into the smaller posterior palatine canal, and transmits the middle palatine nerve and vessels. The pterygoid groove is completed inferiorly by the pyramidal process of the palate bone. groove.

3. The *posterior part* of the inferior region includes all that is situate between the occipital protuberance and a line connecting the mastoid processes. It is divided into two lateral parts by a ridge, extending from the foramen magnum, which occupies its fore part, to the occipital protuberance. From the ridge two rough curved lines branch outwards; these give attachment to muscles, so does the space between them, as well as that between the inferior one and the foramen magnum. At the margin of the foramen, but nearer to its anterior part, are the condyles[15] of the occipital bone, which articulate with the first vertebra; behind each is a depression[16] (*condyloid fossa*), and often a foramen (*posterior condyloid*), which transmits a small vein. The posterior part; bounds; foramina. Occipital condyles.

c. The *anterior region* of the skull is of an oval form; it extends from the frontal eminences to the chin; and from the external border of the orbit and ramus of the jaw, on one side, to the corresponding points on the other, so as to include the whole of the face. The eminences, depressions, fossæ, and foramina observable in this region, are as follow: viz. the frontal eminences, more or less prominent in different individuals, bounded inferiorly by two slight depressions, which separate them from the superciliary ridges; these last curve outwards from the nasal process of the frontal bone. Below the superciliary ridge, on each side, is the margin of the orbit, marked at the union of the middle with the inner third by a groove, or a foramen, which transmits the frontal nerve and supra-orbital vessels; and also by a slight depression, which gives attachment to the cartilaginous pulley of the trochlearis muscle. Lower down, at an interval corresponding with the breadth of the orbit, is another ridge, forming its inferior margin; under which is situate the infra-orbital foramen, for the passage of the superior maxillary nerve and vessels. Still lower down is the fossa canina, which gives attachment to the levator anguli oris muscle; it is bounded below by the alveolar border of the upper jaw, and surmounted by the malar Anterior region; its extent; objects included.

* In some bodies there will be two or more apertures instead of one, in this spot.

tuberosity. In the middle line, and corresponding with the interval between the orbits, is the nasal eminence of the frontal bone, which is prominent in proportion to the development of the frontal sinuses over which it is placed: it is bounded below by the transverse suture, which marks the root of the nose. Below the nasal and between the contiguous borders of the superior maxillary bones, is a triangular opening which leads into the nasal fossæ; it is broad below, and there its edge is surmounted in the middle line by the prominent point of the nasal spines. Laterally it presents two sharp curved borders, which gradually incline inwards as they ascend to the nasal bones, so as to narrow it somewhat. Below the nasal aperture is a slight depression (myrtiform fossa), at each side of the middle line over the alveolus of the second incisor tooth. Farther down is the transverse opening of the mouth, between the alveolar borders of the jaws. In the inferior maxillary bone, besides some muscular impressions, is the labial or mental foramen, which transmits the facial branches of the dental nerve with its vessels.

Lateral regions; their extent.

D. and E. The two *lateral* regions of the skull are somewhat of a triangular figure, the apex of the triangle being below at the tuberosity of the upper jaw, the base at the temporal ridge, and the sides formed by two lines drawn, one forwards, over the external orbital process, the other backwards, internal to the mastoid process. In consequence of the great irregularity of the surface, it is necessary to subdivide each of these regions into three; the part above the zygoma being called the temporal region or fossa, that beneath it, the zygomatic, the remainder being named the mastoid. The last two can be best studied when the lower jaw has been taken away.

Each divided into three parts.

Temporal fossa; its extent and formation.

1. The *temporal* part, or fossa, being bounded by the temporal ridge above, and by the zygomatic arch below, is of a semicircular form, and extends from the external angular process of the frontal bone to the base of the mastoid process. It is filled up by the temporal muscle, lodges the deep temporal vessels and nerves, and is formed by the temporal, parietal, frontal, sphenoid, and malar bones.

Mastoid part; boundaries;

2. The *mastoid* part is bounded before by the anterior root of the zygoma; above by the posterior root and the additamentum suturæ squamosæ; behind by the additamentum suturæ lambdoidalis and the vaginal process. Proceeding

ram ina.

from behind forwards, are the mastoid foramen, and the process of the same name; anterior to this is the aperture of the meatus auditorius externus, which is circular in young persons, and somewhat oval in adults, with the longest diameter from above downwards. This osseous tube, continuous externally with the fibro-cartilage of the ear, and bounded internally by the membrana tympani, is directed obliquely forwards and inwards, and is somewhat broader at its extremities than in the middle. Anterior to the meatus is the glenoid fossa, which is bounded before by the anterior root of the zygoma, behind by the styloid and vaginal processes, and internally by the spinous process of the sphenoid bone. It is divided into two portions by a transverse fissure (*fissura Glaseri*); the anterior portion is smooth, for its articulation with the condyle of the lower jaw; the posterior, rough, lodges part of the parotid gland. This fissure gives entrance to the laxator tympani muscle and a small artery, and transmits outwards sometimes the chorda tympani nerve. Glenoid fossa and fissure.

3. The *zygomatic* part of the lateral region, situate deeply behind and beneath the orbit, is bounded before by the convex part of the superior maxillary bone, and is enclosed between the zygoma and the pterygoid process. The posterior surface of the maxillary bone is pierced by some small foramina, opening into canals, for the transmission of the superior dental nerves and vessels. Between the superior border of this bone and the great ala of the sphenoid, is a fissure (*spheno-maxillary*), which is directed forwards and outwards, and communicates with the orbit; and between its posterior border and the pterygoid process is another (*pterygo-maxillary*), whose direction is vertical. The angle formed by the union of these fissures constitutes the *spheno-maxillary fossa*, which is placed before the base of the pterygoid process, behind the summit or posterior termination of the orbit, and immediately external to the nasal fossa, from which it is separated by the perpendicular plate of the palate bone. Into this narrow spot five foramina open, viz. the foramen rotundum, which gives passage to the second branch of the fifth nerve; the foramen pterygoideum, to the pterygoid or Vidian nerve and vessels; the pterygo-palatine, to a small nerve and vessels of the same name (sometimes called also the superior pharyngeal); the posterior palatine foramen, to the posterior palatine nerve and vessels, and the spheno-palatine, which transmits the spheno-palatine nerve and vessels. Zygomatic region; its bounds. Spheno-maxillary fissure. Pterygo-maxillary fissure. Spheno-maxillary fossa; its bounds and foramina.

THE INTERNAL SURFACE OF THE SKULL.

Divisions.

The internal surface of the skull may be divided into its arch and its base.

The arch; extent and marking of.

The *arch* extends from the base of the perpendicular part of the frontal bone, as far as the transverse ridge on the inner surface of the occipital bone. Along the middle line, and corresponding with the direction of the sagittal suture, is a shallow groove, marking the course of the superior longitudinal sinus. Several slight, irregular depressions for the cerebral convolutions may also be observed, and some tortuous lines for the branches of the meningeal artery; and in many cases irregular depressions mark the position of glandulæ Pacchioni. The surface is more or less depressed, so as to form fossæ, at the points corresponding with the frontal and parietal eminences, and also above the transverse occipital ridge, where the posterior lobes of the brain are lodged.

Depressions for glandulæ Pacchioni.

The base; its three fossæ.

The *base* of the skull presents on the inner surface the several eminences, depressions, and foramina, which have been already enumerated in the description of the separate bones. Three fossæ may be observed at each side, differing in size and depth.

Anterior fossa; the bones which form it;

1. The *anterior fossa*, the shallowest of the three, is hollowed in the middle line, but raised and convex externally. It is formed by the orbital plate of the frontal bone, the smaller wing of the sphenoid, and the cribriform plate of the ethmoid, and serves to support the anterior lobe of the brain: it is marked by eminences and depressions answering to the cerebral convolutions and sulci; and, posteriorly, by a transverse line, indicating the junction of the bones just mentioned. The foramina in the anterior fossa are those in the ethmoid bone for the transmission of nerves and vessels to the nasal fossæ: viz. the olfactory nerve, the nasal branch of the fifth cerebral nerve, and the ethmoidal branches of the ophthalmic vessels.

its foramina.

Middle fossa, formed by—

2. The *middle fossa* is deeper at the outer side than towards the middle line; it is formed by the sphenoid bone, the squamous part of the temporal, and the anterior surface of the pars petrosa; it lodges the middle lobe of the brain. It is marked by linear impressions for the meningeal artery, and by shallow pits for the cerebral convolutions; anteriorly it opens into the orbit by the sphenoidal fissure (sometimes

called foramen lacerum orbitale to distinguish it from those foramina lacera placed farther back and already noticed), which transmits the third, the fourth, and the sixth nerves, together with the ophthalmic branch of the fifth, and the ophthalmic vein. Behind this is situate the foramen rotundum for the second trunk of the fifth, the foramen ovale for the third trunk of the same nerve; and lastly, the foramen spinosum for the middle meningeal vessels. Where the summit of the pars petrosa approaches the body of the sphenoid bone, there the internal orifice of the carotid canal appears. On the anterior surface of the pars petrosa, and directed obliquely backwards, there is a slight groove, leading to the hiatus Fallopii, and transmitting the large petrosal nerve. has foramina.

3. The *posterior fossa*, deeper and broader than the others, extends backwards to the occipital protuberance, and is constructed by the occipital bone and the mastoid and petrous parts of the temporal bone, and gives lodgment to the lateral lobes of the cerebellum. In the posterior surface of the pars petrosa, which limits anteriorly this fossa, may be observed the internal auditory foramen, and about a quarter of an inch behind it, a fissure marking the opening of the aquæductus vestibuli. Towards the inferior margin of this surface is part of the groove for the lateral sinus, which leads down to the foramen lacerum jugulare. Posterior fossa; its position, objects it contains.

Along the middle line, and taking the parts in the base from before backwards, we observe the foramen cæcum, the crista galli of the ethmoid bone, and on each side the cribriform lamella of that bone. Farther back is a slightly elevated surface, which supports the commissure of the optic nerves; and on each side are the optic foramina. Behind this is the pituitary fossa, placed on the body of the sphenoid bone, and bounded before and behind by the clinoid processes. Leading downwards and backwards from these, is the basilar groove, which supports the pons Varolii and medulla oblongata, and terminates at the foramen magnum; at each side of this foramen are the condyloid foramina, and behind it a crista, leading upwards to the occipital protuberance, and giving attachment to the falx cerebelli. Parts along centre of base of skull.

THE ORBITS.

The form of the orbits is that of a quadrilateral pyramid, whose base is directed forwards and outwards, and apex backwards and inwards. If their axes were prolonged The orbits: form, and direction. Axis.

Its centre. Neural arch and ring.

cervical vertebra. Thus, the centre is represented by the basilar process (fig. 18, [19]); the neural ring by the foramen magnum[5]; and the neural arch (neurapophyses) and spine by the expanded hinder part of the bone (fig. 19 B [b.b.a.]). The condyles are the counterpart of the articulating processes (fig. 17, [6]); as the jugular eminences are of the transverse processes of the arch (fig. 18, [20]). The hæmal arch is the loop that supports the upper limbs. In man this is dissociated from the remainder of its appertaining vertebra, but in the fish it remains permanently in connection with the rest of its proper vertebral segment—the occipital.

Hæmal arch.

Peculiarities.

The chief peculiarities in this segment are the increase in the neural arch and spine, and the displacement of the hæmal arch.

Second segment.

Parietal vertebra.—The resemblance of this group of bones to a vertebral segment is at first sight less marked than in the preceding case, though with some attention it may be recognised. For instance, the counterpart of the centre is the posterior part of the body of the sphenoid bone, (fig. 3, A[c])—which is a distinct piece at an early period of the growth of that bone. The neural arch is very large, and is formed by the great wings of the sphenoid bone, n. ap. (neurapophyses) and the parietal bones, n. s. (neural spine). The hæmal arch is here incomplete. It is formed by the hyoidean apparatus, viz., the styloid process of the temporal bone, pl. ap. (pleurapophysis), and the small cornua, h. ap., and the body, h. s., of the hyoid bone (hæmapophysis and hæmal spine).

The centre. Neural arch. Hæmal arch.

Peculiarities.

The visceral arches of this segment exhibit a marked contrast; for, whilst the neural arch is large and perfect, with appropriate articulation of its component pieces, the hæmal arch is atrophied, and is completed for some distance by the stylo-hyoid ligament, which is at times converted into bone.

Third segment.

Frontal vertebra.—The third segment limits the cranium in front, and has a large neural arch like the two vertebræ behind it. The anterior division of the body of the sphenoid in the fœtus—the part supporting the small wings, answers to its centre. The neural arch is constructed by the small wings of the sphenoid (neurapophyses), and by the upper part of the frontal bone (neural spine). The hæmal arch (mandibular) forms the lower boundary to the opening of the mouth: its components are the tympanic portion of the temporal bone (pleurapophysis), which the jaw touches together with the mandible or lower jaw (hæmapophysis and hæmal spine).

Its centre. Neural arch, and hæmal.

The frontal vertebra resembles the occipital with respect to the condition of the neural spine. At an early period of its growth the spine is composed of two separate parts, as in the parietal segment, but these are subsequently united, and so close the cranial cavity in front. Peculiarities.

Nasal vertebra.—In the nasal segment the elements present the usual characters in a less obvious manner than in the other vertebræ of the head. Its centre, which is in advance of the cranium, enters into the construction of the partition of the nose; and, being flattened, forms the bone called vomer. The neural arch not being required to enclose any part of the nervous centre, its elements (neurapophyses) are blended together, and constitute the central portion of the ethmoid bone,—also a part of the nasal septum. The neural spine is represented by the nasal bones. The hæmal arch is found in the roof of the mouth: in it are the palate bones (pleurapophyses), with the upper jaw-bones (hæmapophyses and hæmal spine). Fourth segment. Centre, with neural and hæmal arches.

As this segment is situate chiefly in front of the brain, and does not take any large share in the formation of the cranial cavity, it undergoes greater modifications than any of its fellows. It wants the neural ring, like the coccygeal vertebræ. Peculiarities great.

The cranial segments, as above considered, afford a striking exemplification of the general statement, that variations in the vertebral segments are determined by the special purposes which they serve in the economy of the being, but yet without any departure from the original plan or pattern traceable in the construction of the skeleton. Thus, the centres of the first three cranial vertebræ retain that office of supporting and protecting the nervous centre, which those of other vertebræ possess; while in the nasal one, where the like function is not assigned to the centre, it becomes a thin and almost diaphanous plate of bone, which serves only to separate the nasal fossæ. In like manner an increase in the neural arches is determined by the size of the contained brain, over which they grow; and where parts are not required to enclose the brain, as in the nasal vertebra, the neural ring is wanting. The hæmal arches also undergo transformations, which accord with superadded functions; for instance, that of the occipital vertebra, whilst supporting the upper limbs, has its first element, the scapula (pleurap.), widened for muscular attachments; and lastly, the frontal and nasal loops, which bound the mouth, are additionally Review of difference in the segments. Variations in form adapted to use; as seen in the centres, the neural arches, and the hæmal arches.

provided, in each instance, with a set of bony appendages (the teeth), for the purpose of seizing and crushing the food.

PROPORTION BETWEEN THE CRANIUM AND THE FACE.

Head has two parts; cranium and face. Relative size of these, shows size of the brain and the senses.

The head is composed of two parts, as has been already observed, viz.: the cranium and the face; the one being intended to contain the brain—the material instrument of the mind; the other to enclose the organs of sight, smell, and taste. The more the organs of smell and taste are developed, the greater is the size of the face, and the greater its relative proportion to the cranium. On the contrary, the larger the brain, the greater must be the capacity of the skull, and the greater its proportion to the face. On this principle, a large cranium and a small face indicate a large brain with a restricted development of the senses of smell and taste; but a small cranium and a large face mark an opposite conformation. The characters and the natures of animals are determined by the degree of energy with which their different functions are performed; they are guided and impelled by some leading propensity or disposition; and as the cranium and the face bear to the brain and the organs of sense the relation of containing and contained parts respectively, the study of their relative proportions is one of great interest to the anatomist, inasmuch as these serve as indices of the faculties, instincts, and capabilities of different individuals as well as of classes.

How the proportion between the two can be ascertained.

Several methods have been suggested for determining the proportion of the cranium to the face, but none of these are precise; the simplest is that of Camper. If a line be drawn upwards from the side of the chin, over the most prominent part of the forehead, it will form an angle with a horizontal line drawn backwards over the external auditory foramen from the margin of the anterior nares; the size of the angle will indicate the degree of development of the cranium and brain, as compared with that of the face and organs of sense. In the crocodile these lines are so nearly coincident that there is scarcely any appreciable angle.

In the Horse it measures * . .	23°
Ram	30
Mastiff	41

* Cuvier, Leçons d'Anatomie Comparée, tom. ii. p. 8.

In the Orang-utan it measures* .	30°
European adult . . .	80 to 85

Thus we find man at the top of the scale of animated beings, distinguished from all the rest, as well by his external conformation as by his internal organisation. When the mind has passed in review the many links of the chain which connects the lowest with the highest—the mere animated dot, with man the lord of the creation—it cannot fail to be struck with astonishment at the immense chasm which separates them. Yet, when each link of the chain is compared with that which precedes and follows it, the transition from the one to the other is found to be so gradual as to be almost imperceptible. So easy are the steps of ascent in organisation from the higher orders of the quadrumana, up to the human species, that even Linnæus felt it difficult to assign the specific characters by which man is distinguishable from all other animals; but any doubt that may have existed on this subject has been long since removed. The physical and moral attributes of man are universally recognised as sufficient to elevate him much farther from the higher mammalia than these are from the classes beneath them; and in the opinion of Cuvier,† he should be considered not merely as a distinct species, but even as forming a separate order by himself. Whether, then, with the zoologist, we consider the physical conformation of man as compared with that of other animals, or, with the moralist, reflect on his mental powers and high destination, we can scarcely refrain from saying, with the poet, Man stands highest in the scale of beings.

Sanctius his animal mentisque capacius altæ
Deerat adhuc, et quod dominari in cætera posset.
Natus est homo.

THE THORAX.

The ribbed part of the skeleton—the chest or thorax—is formed by the hæmal arches of the twelve dorsal vertebræ. In seven of the segments, fig. 44, the arches are complete and consist each of three elements, fig. 1, viz. rib (pleurapophysis), costal cartilage or sternal rib [10] (hæmapophysis), and part of the sternum [4] (hæmal spine): in the remaining five the central element or hæmal spine is wanting, The thorax formed by hæmal arches, some complete; some not.

* Owen, Zoolog. Trans., vol. i. p. 373.
† Règne Animal, tom. i. p. 81.

Nature of the sternum.

and the arches remain open. The breast-bone then is but the aggregate of a given number of hæmal spines.

The bones which form the thorax.

Into the composition of the thorax, fig. 44, enter the

Fig. 44.*

sternum and the ribs, which are proper and peculiar to it, and the bodies of the vertebræ, which are common to it and to other parts. The latter have been already described; and the former will now be referred to as separate pieces or bones.

THE STERNUM AND THE ENSIFORM CARTILAGE.

The sternum; its position; shape;

The sternum (os pectoris : xiphoides) is situate in the median line, at the fore part of the thorax:[14] it is flat and narrow, but not of equal width in its entire extent,

* A front view of the thorax, viz. the dorsal vertebræ, the sternum and the ribs, with their cartilages. 1. The first piece of the sternum. 2. is placed opposite the point at which a rib is joined to the sternum. 3. is close to one of the articular surfaces which the sternum has for the clavicle. 4. is on the middle of the second division of the sternum. 5. The ensiform cartilage. 6. The groove which marks the lower margin of a rib. 7. The posterior end of a rib. 8. Its neck. 9. The tubercle. 10. The cartilage. 12. The first rib. 13. Its tuberosity. 14. The first dorsal vertebra. 15. The eleventh; and 16. the last rib.

being broad at its upper part, then narrowed somewhat, after which it widens a little ; finally it becomes compressed and narrow where it joins the ensiform cartilage. Its direction is oblique from above downwards and forwards; and this inclination forwards, together with the curve backwards in the dorsal part of the vertebral column, causes a considerable increase in the antero-posterior diameter of the thorax. We have to consider successively its surfaces, extremities, and borders. and direction.

The *anterior surface*, slightly convex, and subjacent to the skin, is marked by four transverse lines, indicating the original division of the bone into five pieces. The union between the first and second of these pieces (opposite the insertion of the second costal cartilage) is frequently cartilaginous even in adult age. Its surfaces; anterior, marked by lines;

The *posterior surface*, somewhat concave, looks towards the cavity of the thorax, and gives attachment, superiorly, to the sterno-hyoideus and sterno-thyroideus muscles ; inferiorly, to the triangularis sterni. posterior.

The *borders* are thick, and each is marked by seven angular depressions for the reception of the cartilages of the true ribs, which give it a notched or serrated appearance. Lateral margins.

The *superior extremity*, broad and thick, is slightly excavated from side to side, and presents at each corner a depression for the reception of the sternal end of the clavicle. The upper end.

The sternum, in early infancy, is divided into several pieces, but in adult age two only remain distinct. These two pieces, with the ensiform appendage, at one time received names derived from an imputed likeness of the whole to a sword ; but the last-mentioned part alone retains the designation grounded on this circumstance.* Why named sword-like.

The first division of the sternum[1] (manubrium or handle) is broader and thicker than the other ; its form is nearly square. The lateral margins, thin and oblique, present each an oblong depression,[2] which receives the cartilage of the first rib ; and at each inferior angle may be observed a The first piece.

* Vesalius, whilst stating that others regarded the sternum and ensiform cartilage as resembling a sword, prefers to compare the pieces of the sternum to the handle only of that weapon, adding, in support of his view, the curious reason, thus expressed (Lib. i. p. 115), "Secundum autem os, illi parti congruit, quam manus tota intus complectitur, in qua sinus costarum cartilaginibus parati, eum præstant usum, quem in gladiis ex manubrii asperitate quærimus, quoties intortis nodosisq' funiculis, aut scabra piscis cute, illud obduci curamus."

Its borders

and angles.

half notch, which articulates with the cartilage of the second rib. The superior border is hollowed, and hence the name *incisura semilunaris* or *furcula*, which has been applied to it: at the angles which terminate it are the fossæ,[3] which articulate with the clavicles, as has been already stated. The inferior border is straight, and united to the upper extremity of the second piece.

The second piece.

Surfaces,

Borders,

The second division,[4] (the body,) much longer than the first, is marked on its anterior surface by some transverse lines, which indicate its original division into separate portions. Both surfaces are nearly flat. The upper extremity is narrow, corresponding in breadth with the termination of the first piece, with which it is connected by cartilage. The lateral borders present each five notches for the reception of the cartilages of the five lower true ribs, and a half notch superiorly, which, with a similar depression in the first piece, forms a cavity for the second costal cartilage. The five inferior notches approach one another more closely in proportion as they are situate lower down, and part of the last is occasionally made up by the ensiform cartilage.

Peculiarities.

If the sternum is examined in several adult skeletons, it will be found to differ in form,—*i. e.* in the length of its parts, as well as in its breadth at given points;—but these differences are very various, and are not so considerable as to require detailed notice. Other peculiarities, less frequently met with, and of more interest,—such as divisions running through the bone, and perforations of its substance,—will be treated of more conveniently in the account to be given of the ossification; for there the manner of their production can be explained by reference to the process of growth.

The ensiform cartilage;

varies in shape,

The inferior extremity of the sternum, thin and elongated, gives attachment to a cartilaginous appendix,[5] called the *ensiform* or *xiphoid* (ξιφος, a sword; ειδος) cartilage, which in most instances remains partly cartilaginous until an advanced period of life. Its form varies considerably in different individuals:—it is sometimes bent forwards, sometimes in the opposite direction, and sometimes pierced by a hole at its centre (fig. 45, A, B, D). It gives attachment to the aponeurosis of the abdominal muscles.

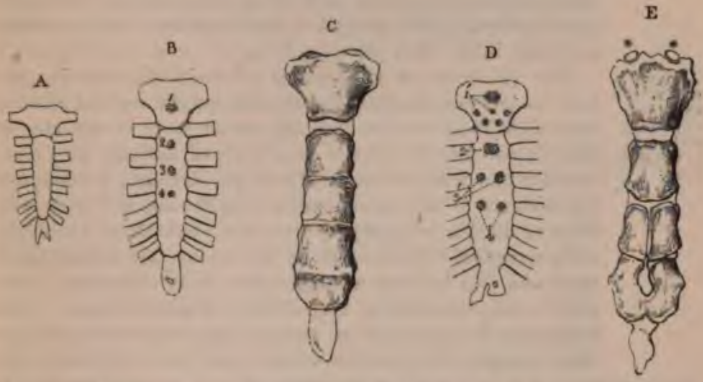
Connection with other parts.

Articulations.—The sternum articulates by its lateral borders with the cartilages of the true ribs,—by its upper angles with the clavicles, and by the lower end it is connected to the ensiform cartilage.

When sawed across, this bone presents a considerable quantity of loose spongy texture in its interior, with a very thin lamella of compact tissue on its exterior; hence it is very light. Structure.

Ossification.—As far as the middle of fœtal life, or a little later, the sternum is altogether cartilage (fig. 45, A). After Ossification.

Fig. 45.*



that time the ossification begins with the formation of osseous granules in the middle of the intervals between the points at which the cartilages of the ribs are connected. There are five of these for the sternum exclusive of the ensiform appendage, and they form as many pieces. The process of ossification makes its appearance in the first piece between the fifth and sixth months, and soon following in the second and the third, it reaches the fourth at the end of fœtal life. The osseous centre of the last (fifth) varies considerably in the time of its appearance. It may be found soon after birth, or may not be visible for a considerable time (one or two years) after that period. Situation of the nuclei. Time of their appearance.

In many cases one or more of the divisions of the sternum are formed from more nuclei than one, and there Variations in their number;

* Various conditions of the sternum are represented in these figures. They are described incidentally in the text. 1. The osseous nucleus of the first piece. 1′. Several granules for the same. 2. The nucleus of the second piece. 3, 4. Those of the third and fourth. 3′, 4′. Double nuclei for the same. * * The epi-sternal granules.

are peculiarities with respect to the number and position of these additional granules which require notice.

in the first piece;

The first piece has often two points of ossification, placed usually the one above the other ; and it has been found to possess three. A number, which I believe to be very unusual (six), are contained in the preparation represented in figure D, 1′. The second has seldom more than a single granule (B, D²), but the third, fourth, and fifth pieces are frequently formed each from two nuclei, which are placed laterally with respect to one another,—not vertically, as occurs in the first piece (D, 3′ 4′).

in the others.

Applied to explain the existence of division and holes in the sternum.

The presence of two points of ossification having the relative position mentioned, accounts for the vertical division sometimes found to run through one or more of the sternal pieces ; and the occurrence of a hole, of various size, occasionally met with in the middle of the sternum, is explained by reference to the same peculiarity in the manner of growth. Thus :—in the ordinary course, the ossification extending uninterruptedly inwards from the nuclei, the lateral parts meet and join to form a single piece before junction takes place with the portion immediately above or below. But supposing the formation of bone to cease when the parts are close together, the division which in all such cases exists for a time will become permanent, and if the growth should cease sooner, a larger interspace (a hole) will be the result (fig. 45, E). Farther, if the interruption to the progress of ossification should occur at the point where the lateral parts of two sternal pieces would meet, the hole is likely to have considerable size, for it may then result from an "arrest of the development" affecting four centres.

Union begins at the lower end.

The five pieces of the sternum constructed in the manner above detailed begin to join at the lower end of the bone. The fifth piece is joined to the fourth soon after puberty, the fourth and the third are united between twenty and twenty-five years of age, and the body of the sternum is usually not completed by the junction of the third piece to the second before thirty-five or forty years. Lastly, the first division does not in general join with the rest of the sternum at any period ; but should its union take place, it is to be met with only in old age.

Epi-sternal nuclei.

To the centres of ossification here described, M. Breschet*

* "Recherches sur différentes Pièces du Squelette des Animaux Vertébrés," &c. in "Annales des Sciences Naturelles," 2ᵉ Série, t. 10 (Zoologie), p. 91.

has added two small epi-sternal granules, whose position is sufficiently indicated by the asterisks ** in figure E. They occur only at rather advanced periods of life; and they do not appear to be constant.

Ensiform appendage.

The *ensiform* appendage begins to ossify some years after birth,—the time in different cases varying, according to the observation of Béclard, between two years and fifteen or eighteen. The ossification proceeds from a single centre situate at the upper part, and from this it gradually extends downwards; but in most instances a portion remains cartilaginous even in very advanced life.

THE RIBS AND THEIR CARTILAGES.

The ribs; their number;

The *ribs* (costæ*) extend from the vertebral column towards the middle line of the body in front, forming arches, which construct the lateral parts of the thorax. They are usually twelve in number at each side, but it occasionally happens that the number is augmented by the addition of a cervical or a lumbar rib, to which reference has already been made in describing the vertebræ of those regions. The number may also be diminished to eleven: I have lately seen an instance in which this diminution was accompanied with the absence of a dorsal vertebra. The seven superior pairs, which are united by means of cartilaginous prolongations to the sternum, are called *sternal* or *true ribs;* the remaining five, which are not prolonged to the sternum, being denominated *asternal* or *false ribs.*

divided into true and false;

The ribs, as they reach forwards, have not a uniformly arched direction; for the greater number consist of segments of two circles with different diameters, the anterior circle being much the larger. Thus the rib, directed at first backwards from its connection with the bodies of the vertebræ, reaches and is supported by the transverse process; after leaving the extremity of this process, it turns abruptly outwards, and finally is directed forwards towards the middle line.

their direction.

These bones present each two surfaces, two borders, and two extremities.

Parts of a rib.

The body of the rib, except that of the first, is as it were twisted on itself, so that, when it is placed on a plane

Body and

* "As if they were *custodes* of those principal organs of the animal machine, the heart and lungs."—Monro, "The Anatomy of the Human Bones," p. 234; Edinb. 1726.

lies the latissimus dorsi muscle. At the convergence of the superior and inferior borders is the *anterior* or outer angle, which presents a narrow constricted part,[13] denominated the neck, with a shallow surface for the shoulder-joint.

Neck of the scapula.

The *neck* (cervix scapulæ) separates the glenoid fossa and the coracoid process from the rest of the bone, and terminates above at the notch of the scapula.

Glenoid cavity;

its shape,

direction.

The articular surface of the bone, which is called the *glenoid cavity* (γληνη, a superficial cavity; ειδος), is surrounded by a slightly raised rim which gives attachment to the capsule of the shoulder-joint. It is a shallow, oval depression, broader below than above, and covered with cartilage in the fresh state; its longest diameter is the vertical, and its direction outwards and forwards. In this last respect, however, it varies considerably; for during the more extended motions of the humerus, the scapula is made to turn, as it were, on a pivot driven through the centre of its dorsum, by which means the glenoid cavity is kept constantly in apposition with the head of the humerus, and this coaptation is the chief security against its dislocation. At its upper part is an impression corresponding to the attachment of the tendon of the biceps muscle.

Connection with other bones.

The scapula *articulates* by the glenoid cavity with the humerus, and by the acromion process with the clavicle.

Ossification.

Primary nucleus; time of its appearance.

It forms the greater part of the bone.

The scapula has several centres of *ossification*, and the greater part of the bone, as in most other cases, is formed from one of them. This nucleus appears at the time that osseous matter is first deposited in the vertebræ; and from it the ossification spreads in different directions,—to the spine and the glenoid cavity—in short through all the bone, except the coracoid process, the acromion, the lower angle, and the base, each of which is a distinct formation.

At birth the parts last named are cartilaginous.

Coracoid process.

An osseous granule appears in the middle of the coracoid process (fig. 48, A[2]), usually in the course of the first year after birth, and this part, being largely ossified, has joined, or is about to join the rest of the scapula when the remaining pieces begin to form.

Situation and succession of other ossific points.

The additional centres of ossification succeed each other rapidly, between the fifteenth and seventeenth years, generally showing themselves in the following order:—1. in the acromion near the base;—and in the upper part of the coracoid process; 2. in the lower angle; 3. again in the

acromion ; 4. in the base. The several pieces constructed from these nuclei may be regarded as epiphyses. Each of them requires some remark.

Fig. 48.*

The acromion: its parts formed differently.

The base of the acromion is an extension through the spine from the primary centre of ossification, and the extent to which the ossification from this source reaches varies in different cases (fig. 48). The remainder of the process is produced from two or more irregular nuclei ($c^{3\,3}$), which unite the one to the other, and form a single piece to be subsequently joined to the spine, or rather to the projection from this (fig. 48, D).

Epiphysis of the coracoid process.

On the convex part of the coracoid process where it turns forward, a thin scale (an epiphysis) forms after the process

* The scapula is here represented at various periods of its growth. The figure marked A. shows the condition of the bone at about the end of the first or the beginning of the second year of age ; ossification has largely extended from the primary centre, and a nucleus has appeared in the coracoid process. B. From a boy aged about fifteen or sixteen years ; the coracoid process is partly joined at its base, and nuclei have appeared in the acromion and in the lower angle. C. shows the condition of the bone at seventeen or eighteen years of age. A second point has formed in the acromion, and the ossification of the base is advanced. D. The scapula of a man about twenty-two years of age. The epiphyses of the acromion and the base are still separable. A thin epiphysis, which exists on the coracoid process of the preparation represented in the sketch, has been accidentally omitted. N.B. One of these figures (C) is to be regarded as altogether an illustrative plan. I do not possess a preparation showing this stage of the growth of the bone.

has been joined on to the general mass of the scapula. I have observed this epiphysis to be in general broad at the upper part, and to taper downwards to the notch in the upper margin of the scapula.

The lower angle. The base. The lower angle and the contiguous part of the base are produced from one centre (B, C, D,[4]). The remainder of the base is also to be considered a distinct growth; but from the appearance of completeness presented in some scapulæ of young bodies, I think it not unlikely that a portion of it is occasionally formed by extension from the general ossification of the bone. The point, however, requires further investigation.

Completion. The epiphyses are joined to the bone between the ages of twenty-two and twenty-five years.

THE CLAVICLE.

The clavicle; its position, The clavicle (*clavis*,* a key), or, as it is popularly called, the collar-bone, is extended, transversely, between the acromion process of the scapula and the summit of the sternum, which it serves to connect; its direction, however, is not exactly horizontal, the acromial end being slightly elevated. This bone is curved somewhat like an italic *f*, the degree of the curvature being less in the young and in females, than in male adults; it is rather thick and somewhat triangular towards its sternal end, but broad and flat towards the scapular extremity; it presents for examination a body and two extremities.

(Margin notes: direction, shape, division into parts.)

The body; its upper surface subcutaneous; lower surface uneven. The superior surface of the *body* is principally subcutaneous. The inferior surface presents, near the sternal and acromial ends, inequalities for the attachment of ligaments; and along the centre is a longitudinal depression, giving attachment to the subclavius muscle, with a foramen for

* Various reasons have been assigned for the name by which this bone is distinguished. It is said to have been taken from the likeness to a peculiar form of key. By most writers the name is considered to have been derived from uses attributed to the bone: such as that, key-like, it closes the chest; or that, as "a stay," it connects the scapula to the trunk. Thus, Riolanus—who is cited because of his character for extensive erudition—says (Comment. de Ossibus, cap. 21), "Clauis siue clauicula dicitur quod Thoracem claudat . . . Nam ex Aristotele Clauis, os claudens thoracem et instrumentum quo aliquid clauditur significat. . . . Vel quia clauis modo firmet et stabiliat cum sterno omoplatam. In architectura claues appellantur ligna aliis firmitudinem præstantia."

the entrance of the nutritive vessels; this surface corresponds internally to the first rib, externally to the coracoid process and the shoulder-joint, and in the middle to the axillary vessels and the brachial plexus of nerves. The anterior border is broad and convex towards the sternal, thin and concave towards the scapular extremity; the posterior border presents, of course, the opposite arrangement of curvatures.

Ends of the bone; their differences.

The *internal* or *sternal* extremity is inclined downwards and forwards: it is considerably thicker than the other parts of the bone, and terminates in a triangular unequal surface, which is rather convex from above downwards, and concave from behind forwards; this is tipped with cartilage, and articulates with the sternum, the articular surface of which it much exceeds in size. Its entire circumference gives attachment to ligaments. The *external* or *scapular* extremity, compressed and flattened, inclines a little backwards and upwards, and articulates with the acromion by a narrow oblong surface which is covered with cartilage.

Articulations.

Articulations.—The clavicle articulates with the sternum and the acromion process of the scapula.

Various peculiarities of shape and thickness.

Peculiarities in the sexes and individuals.—The clavicle of the female is more slender and less curved than that of the male. But occasionally instances occur which do not conform to this general statement—which are even directly opposed to it. These exceptional cases are in a great measure, if not altogether, referrible to circumstances which will be noticed in the following paragraph. The bone is also less bent in young persons than in adults.

Curve altered by exercise.

The curves of the bone are greatest in persons employed in laborious occupations, and its ends become enlarged under the influence of the same circumstances. It has likewise been found that, from the same cause, a difference may exist between the clavicles of the same person—insomuch that M. Cruveilhier states, that he was enabled to predicate correctly that a person was left-handed, founding his judgment solely on the relative size of the sternal ends of the clavicles.

Fig. 49.*

Ossification.

Ossification.—The clavicle begins to ossify before any other bone. It is formed from one principal piece; and

* *a*. The clavicle of a fœtus. *b*. This figure is taken from the

it has a thin epiphysis at its inner or sternal end. The epiphysis begins to form between the eighteenth and twentieth year; and it unites to the rest of the bone a few years after.

THE HUMERUS.

The humerus; The humerus or arm-bone (fig. 50; os humeri), the largest bone of the upper limb, extends from the scapula to the bones of the fore-arm, with each of which it is articulated. Its direction is vertical, with an inclination inwards towards the lower end. division into parts. Long and irregularly cylindrical in form, the humerus is divisible into a body and two extremities.

Fig. 50.*

The shaft divided by two lines. The *body* or *shaft* of the bone,[1] thick and rounded superiorly, is somewhat expanded and triangular inferiorly. Along the front is a central prominence. On each side of the bone is a slight line, which is better seen below; these lines divide it into two nearly equal surfaces, anterior and posterior, and may be considered as rising from the external and the internal condyles respectively, near to which they are well marked, but gradually subside as they proceed upwards on the body of the bone: they afford attachment to the inter-muscular aponeuroses. Groove for large nerve and an artery. The external one is interrupted about the middle, by an oblique depression, or groove,[4] which runs from above downwards, and marks the course of the musculo-spiral nerve and superior profunda artery. Surfaces. The posterior, The *posterior* surface is round superiorly, and inclined a little inwards; inferiorly it is broad, flat, and turned rather outwards: it is covered

clavicle of a man who had attained to about twenty-three years of age. N.B. The epiphysis is represented of somewhat greater size (thicker) than it is in nature.

* The humerus of the right side seen from before. 1. The shaft. 2, 3. The external and internal condyloid ridges. 4. Opposite part of a shallow groove which corresponds to the course of the musculo-spiral nerve and the superior profunda artery. 5. The bicipital groove. 6. Its anterior margin. 7. Its posterior margin. 8. Foramen for nutritious artery. 9. Deltoid impression. 10. The head. 11. The neck. 12. The great tuberosity. 13. The small one. 14. The inner condyle. 15. The outer condyle. 16. Rounded articular surface (capitellum) for the radius. 17. Trochlea. 18. Fossa for the coronoid process.

in its entire extent by the triceps extensor muscle, and towards its middle may be observed a small foramen for nutritive vessels. The *anterior* surface is divided superiorly into two unequal portions by a longitudinal groove,[5] directed obliquely downwards and inwards, for about one-fourth of the length of the bone, which lodges the long tendon of the biceps muscle, and is therefore named the *bicipital* groove; its anterior margin[6] gives attachment to the pectoralis major; the posterior,[7] to the teres major muscle. The portion of the anterior surface which is internal to this groove is smooth in the greater part of its extent, and presents, towards its middle, a roughness for the insertion of the coraco-brachialis, and lower down an oblique vascular foramen;[8] external to the groove, and a little above the middle of the bone, may be observed a rough triangularly-shaped eminence,[9] for the insertion of the deltoid muscle, below which runs the oblique depression already noticed as corresponding to the course of the musculo-spiral nerve and the accompanying vessels.

and anterior.

Bicipital groove.

Foramen for nutritious artery.

Rough surface for deltoid muscle.

The *superior extremity* of the bone presents a large hemispherical eminence,[10] covered with cartilage in the fresh state, and directed backwards and inwards to the glenoid cavity of the scapula, with which it articulates; this is called the *head* of the humerus. It is bounded by a slight groove, which is sufficiently marked on the upper, but not on the under aspect, which marks the *neck* of the bone.* The axis of this part does not coincide with that of the rest of the bone:— supposing the humerus in its natural position, with respect to the scapula, if the axis of its shaft be vertical, that of the head and neck of the bone is directed backwards and upwards. A little below, and to the outside of the head, are two eminences, which project from the ends of the shaft of the bone, and from their relative size, are named the greater and smaller tuberosities (tubercula). The *greater tuberosity*[12] is external and posterior in its situation, convex in its outline, and marked on its upper border by three flat surfaces for the insertion of the external rotator muscles. The *smaller tuberosity*,[13] rounded and more prominent than the other, gives attachment to the subscapularis muscle. They are separated by the bicipital groove.

The upper end.

The head.

Neck.

The axis of the shaft and that of the upper end of the bone do not coincide.

Tuberosities; their differences.

* This is called sometimes the "anatomical neck." The term "surgical neck" is applied to the somewhat constricted part of the humerus below both the tuberosities and the head.

The lower end is broad.

The lower extremity.—Towards its lower third the bone widens, and appears compressed and somewhat twisted from behind forward, so that its longest diameter is transverse. It presents internally a considerable projection,[14] the *inner condyle*, which is inclined backwards, and gives attachment to the internal lateral ligament of the elbow-joint, also to a tendon common to the greater number of the anterior muscles of the fore-arm. Externally is situate another smaller process,[15] the *external condyle*, to which are attached the external lateral ligament and a tendon common to muscles at the posterior and external surfaces of the fore-arm. Between the condyles is placed the inferior articular surface, which is inclined somewhat forwards. Proceeding in the enumeration of the parts which enter into its composition from the radial to the ulnar side, there is first a rounded eminence, the *small head, capitellum*,[16] placed rather on the anterior surface of the bone, and articulating with a cavity observable on the superior extremity of the radius. Next, a slight groove or depression, corresponding with the inner margin of this eminence, is met with. And lastly a pulley-shaped surface[17] named *trochlea*, whose internal lip is most prominent, and descends much lower than the external; this determines an obliquity in the direction of the humerus, when the lower extremity of the bone is made to rest on a flat surface. In the groove of the trochlea the sigmoid cavity of the ulna moves in flexion and extension. At the fore part of the inferior extremity of the bone, immediately above the trochlea, is a superficial depression,[18] which receives the coronoid process of the ulna during flexion; and more externally is a second smaller pit above the capitellum. Posteriorly is a more considerable median fossa, which lodges the olecranon during the extension of the fore-arm.

Inner condyle prominent.

External condyle.

Articular surface; its peculiarities.

Capitellum.

rochlea.

Fossæ for the bones of the fore-arm.

Other names for the parts of the lower end of the bone.

A modification of the nomenclature applied to these different eminences has been proposed by Chaussier: retaining the term trochlea for the surface of articulation with the ulna, he calls that which articulates with the radius, the condyle; and for the two lateral eminences of insertion, now named condyles, he substitutes the terms *epi-trochlea* and *epi-condyle*.

Articulations.

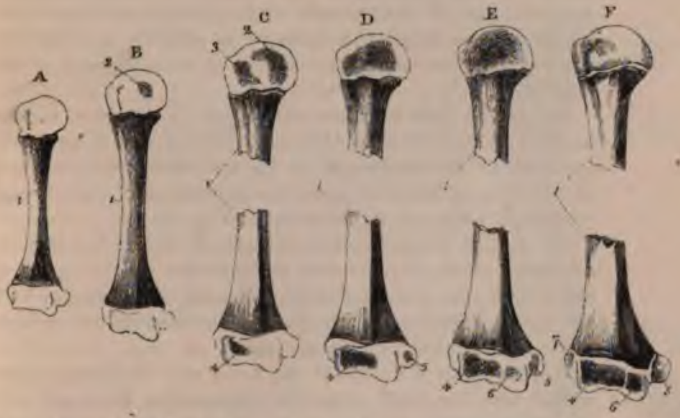
Articulations.—The humerus articulates with the glenoid cavity of the scapula, and with the ulna and radius.

Ossification.

Ossification.—The humerus begins to ossify soon after the clavicle, and some time before the vertebræ. From a small

cylindrical piece, appearing at the middle, the formation of bone extends towards the extremities, involving the entire shaft.

Fig. 51.*



At the end of fœtal life the shaft of the humerus is ossified nearly in its whole length, and its ends are altogether cartilaginous (fig. 51, A). The shaft.

There is a trace of bony deposit in the head of the bone towards the close of the first year after birth, and in the course of the second year a distinct nucleus has formed in this part (B²). Between the second and third years a separate centre is developed for the tuberosities (C³). (Béclard mentions two—one for each tuberosity,—that for the smaller being very small and appearing after the fourth Upper end; difference of statement.

* Several stages in the ossification of the humerus are shown in these figures. That marked A. is the representation of the bone of a full-grown fœtus. B. The condition of the bone at about two years of age. C. The bone in the third year. D. At the beginning of the fifth year. E. The state of the bone about the twelfth year. F. This bone is from a person about the age of puberty.—1. The primary piece. 2. Nucleus for the head. 3. That for the tuberosities. 4. For the outer part of the lower articulating surface. 5. For the inner condyle. 6. The inner part of the lower articulating surface. 7. The external condyle.

N.B. The separated centres of the upper extremity of the bone in figure C. have not been drawn from a preparation.

Some of the bones are represented in two parts, in order to make up in some degree for the absence of the proper proportion in their dimensions.

year.) The osseous nuclei of the head and tuberosities increase, join, and form a large epiphysis before the fifth year (fig. 51, D).

Lower end. The growth of the lower end of the bone is more complicated. It begins after the expiration of the second year, in the outer part of the articular surface—the small head (C [4]), and from this point the ossification extends inwards and forms much the larger part of the articulating end of the bone (D, E, F,[4]).

Before the fifth year an ossific point is deposited in the internal condyle (D[5]).* At about twelve years of age one is apparent in the inner part of the articulating surface; and at thirteen or fourteen years the ossification of the external condyle is begun by a distinct centre (E, F,[6 7]).

Soon after the last-mentioned period, at about sixteen or seventeen years, the external condyle and the two parts of the articulating surface (being previously joined) unite with the shaft of the bone. The junction of the internal condyle follows at about the eighteenth year.

Junction of the epiphyses. And thus all the parts of the lower end of the bone have united with the shaft, while the epiphysis of the upper end, whose formation began first, is still separate. Lastly, this too is no longer separable, and the bone is complete about the twentieth year.

THE RADIUS.

Radius; its length, position, form. The radius (fig. 52,[1]) shorter than the ulna by the length of the olecranon process, is placed at the external side of the forearm, extending from the humerus to the carpus. It is broader below than above, slightly curved in its form, and divided into a body and two extremities.

The shaft triangular. Anterior surface. As *the body*, or *shaft*, is somewhat triangular, it has three surfaces, bounded by three margins, or ridges. The *anterior surface*[1] expands towards the lower part, and is marked by a longitudinal groove for the flexor pollicis longus; superiorly

* As the date mentioned for the appearance of this centre of ossification is much earlier than that assigned by writers who treat of this department of anatomy, it may be well to state, that in one preparation in my collection, which was taken from a boy ascertained to have been a little over six years of age at the time of his death, the ossification of the inner condyle is well advanced;—and that in another—the arm of a female child which I amputated in consequence of an accident on the day after it had attained the fifth year—a small osseous granule is distinctly formed in the same part.

is situate the foramen,[2] for the nutritive vessels, its direction being from below upwards; and inferiorly a flat surface,[3] corresponding with the pronator quadratus. The *posterior surface*, convex in the greater part of its extent, is grooved at its central third, for the origin of the extensors of the thumb; the *external surface*, rounded and convex, is marked towards its middle by a rough impression,[4] which gives insertion to the pronator radii teres. Of the *margins* separating these surfaces, the posterior is distinct only at the middle part; the external is rounded, and becomes smooth towards the lower extremity; whilst the internal is acute and sharp for the attachment of the inter-osseous ligament. The body is terminated superiorly by a rough prominence[5] (tuber radii), termed the *bicipital tuberosity*, from its giving insertion to the biceps muscle. Foramen for vessels. Posterior surface. External surface. The three margins. Bicipital tuberosity.

Fig. 52.*

Above the tuberosity the bone becomes narrowed and constricted into the form of a *neck*; this is again surmounted by the *head*,[7] which articulates by its extremity with the rounded convex part of the lower extremity of the humerus,—the small head (condyle, Chaus.), while its margin rolls on the lesser sigmoid cavity of the ulna. The margin of the head is smooth and convex; and the upper surface, also smooth, presents a shallow cup-like cavity: both are covered with cartilage in the recent state. The upper extremity. Neck. Head; its concave articular surface.

The radius at its lower part becomes broad and thick. The anterior surface is flat and expanded, being covered by the pronator quadratus muscle; and it is bounded below by a prominent line,[8] which gives attachment to the anterior ligament of the wrist-joint. The posterior surface is convex, and marked by longitudinal grooves, which transmit the The lower extremity. Grooves for tendons behind.

* The radius and the ulna of the right side viewed in front. 1. is on the middle of the radius—its anterior surface. 2. points to the medullary foramen. 3. A flat surface near the lower end. 4. A rough impression for the pronator teres muscle. 5. The bicipital tuberosity. 7. The head. 8. The lower margin. 9. The styloid process. 10. Articulating surface for the ulna. The remaining numbers are affixed to the ulna. 11. The anterior surface. 12. The medullary foramen. 13. The olecranon. 14. The coronoid process. 15. The large sigmoid notch. 16. The head. 17. The styloid process.

on the ulnar side, with the cuneiform; on the radial side, with the scaphoid; anteriorly and posteriorly it gives attachment to ligaments. It articulates with five bones.

THE CUNEIFORM BONE.

Cuneiform. This is the "wedge-shaped" bone;[3] sometimes also it is named from its form "pyramidal," as well as "os triquetrum."

Connections. Superiorly, it is in relation with the inter-articular fibro-cartilage of the wrist-joint; inferiorly, it articulates with the unciform bone; on the ulnar side, gives attachment to ligaments; on the radial side, articulates with the semi-lunar bone; anteriorly it affords attachment to ligaments, and presents a small articular surface for the pisiform bone. It articulates with three bones.

THE PISIFORM BONE.

Pisiform; why named. The "pea-shaped" bone[4] is placed on a plane anterior to the other bones of the carpus. The form is indicated by its name (pisum, a pea), and to it is due another designation —os subrotundum. Connections. It presents but one articular surface, which is situate on the posterior part, or base, and rests on the anterior surface of the cuneiform bone.

Adaptation of the first range to the second and to the fore-arm. The first three carpal bones form, when in apposition, an arch, whose superior convex and rounded articular surface corresponds with the concavity presented above by the radius and the inter-articular fibro-cartilage. The greater part of its inferior surface constitutes a deep hollow, which receives the head of the os magnum and a small part of the unciform bone; but on the outer side a part of this range (the lower convex surface of the scaphoid) is received into a slight depression of the second row, formed by the trapezium and trapezoid. (See fig. 55.)

BONES OF THE SECOND ROW.

THE TRAPEZIUM.

Trapezium. The name of this bone[5] is taken from its presenting four unequal edges at its posterior aspect, and it has also been known as the "os multangulum majus." It is placed at the radial border of the carpus, between the metacarpal

bone of the thumb and the scaphoid bone. It is known by the angular appearance of its dorsal surface, and by the groove on its palmar aspect. How distinguished.

Superiorly concave, it articulates with the scaphoid bone; inferiorly, convex from behind forward, and concave transversely, with the first metacarpal bone; on the ulnar side, with the trapezoid bone, and, by a small surface situate more inferiorly, with the edge of the second metacarpal bone; on the radial and posterior aspects it gives attachment to ligaments; anteriorly it presents a groove[6] traversed by the tendon of the flexor carpi radialis, and a ridge to which the annular ligament of the carpus is attached. It articulates with four bones. Connections. Groove and ridge.

THE TRAPEZOID BONE.

This is a small bone[7] compared with those between which it is placed, viz. the trapezium, scaphoid, and os magnum; in form and position it has some resemblance to a wedge, and but little to a trapezium, except that its posterior surface is bounded by four unequal edges. In contradistinction to the preceding bone, this has received the name "os multangulum minus." Trapezoid: Small size. Name.

It articulates superiorly with the scaphoid bone; inferiorly, with the second metacarpal bone; on the ulnar side, with the os magnum; on the radial side, with the trapezium; the anterior and posterior surfaces afford attachment to ligaments. It articulates with four bones. Connections.

OS MAGNUM.

This[8] is the largest of the carpal bones; its form is oblong, round superiorly, cubic inferiorly. The upper part, named its "head," (whence it is sometimes called os capitatum) is supported by a narrowed portion, called the "neck;" and, convex in form, is received into a cavity formed by the scaphoid and the semi-lunar bone. The bone articulates, inferiorly, by three distinct surfaces, of which the middle is the largest, with the second, third, and fourth metacarpal bones; on the ulnar side, with the unciform bone; on the radial side, with the trapezoid bone. The anterior and posterior surfaces are rough (particularly the former) for the attachment of ligaments. It articulates with seven bones. Os Magnum. Head and Neck; connected with three metacarpal bones.

THE UNCIFORM BONE.

Unciform; its "hook." The hook-shaped bone[9] (uncus, a hook) is very readily distinguished from the rest by the curved process[10] upon its palmar surface. Articulations. It articulates, superiorly, with the semi-lunar bone; inferiorly, by two distinct surfaces, with the fourth and fifth metacarpal bones; on the ulnar side, with the cuneiform bone; on the radial side, with the os magnum: anteriorly its hooked process affords attachment to the anterior annular ligament of the carpus; posteriorly a rough surface also gives attachment to ligaments. It articulates with five bones.

THE METACARPUS.

Metacarpal bones; This forms the second or middle portion of the hand, being situate between the carpus and the phalanges; it is composed of five bones, which designation. are named first, second, &c. in their numerical order, the enumeration being commenced at Position. the radial side. These bones are placed parallel one with another, and nearly on the same plane; with the exception of the first, which is more anterior than the rest, and alters its relative position to them in its various movements.

Fig. 56.*

Form. They are all slightly concave on the palmar surface, convex on the dorsal; are larger at their extremities than at the body or middle part; and are terminated at the carpal extremity by an unequal eminence, and at the digital by a rounded head.

Bodies. Shape. The *bodies* of these hand-bones are triangular in shape, each presenting three surfaces, and as many borders. Of

* The bones of the hand—carpus, metacarpus, and phalanges—seen on the palmar surface. For explanation of the numerals on the carpal bones, see note, p. 127.

the surfaces, two are placed laterally, the third looks backwards; one of the angles is in front, the others are at each side of the dorsal surface. From this position of the surfaces, it results that the bones become narrow towards the palmar aspect of the hand, and that the spaces between them (*inter-osseous*) increase from behind forward. Inter-osseous spaces.

The body of the first metacarpal is less triangular than that of some of the others; it is more compressed from before backwards, and resembles one of the phalanges in shape. There are some slight peculiarities of the dorsal surface in the several metacarpal bones. This is convex and smooth in the first, and presents in the second, third, and fourth, a longitudinal line, which, bifurcating, forms the sides of a triangular surface, extending over the lower two thirds of the length of the bone; in the fifth is observed a prominent longitudinal line, directed obliquely from the ulnar to the radial side. Difference in bodies; especially on dorsum.

The metacarpal bones vary in size. The first is thicker and shorter than the others. The second and third do not differ strikingly from each other in dimensions, and they are longer than the rest. The fourth exceeds the fifth in size. Differences in size of bones.

The *carpal extremity* (*base*) presents, in each, some peculiarities which render a separate description necessary.—By referring to the differences in their carpal extremities, the bones may be distinguished one from another, and the more readily if their relative size be at the same time taken into account. On the superior extremity of the first is observed a surface, concave in the antero-posterior direction, and convex from side to side, which articulates with the trapezium; this bone has no lateral articulating surface.— In the second, an angular depression receives the trapezoid bone, and, on the radial side, a small surface articulates with the trapezium; on the ulnar side, the margin is extended obliquely upwards, so as to become wedged in between the trapezoid and the third metacarpal bone, and articulates by its tip with the os magnum.—In the third, the end of the bone, which articulates with the os magnum, is prolonged behind into a point at the radial margin; on the radial and ulnar sides are surfaces for articulation with the contiguous metacarpal bones.—Two articular surfaces of the fourth join with the os magnum and unciform; the radial side has two surfaces, and the ulnar side one, for articulation with the corresponding surfaces of the bone on each side.— In the fifth, a concave surface, directed outwards, corre- Bases are characteristic. Base of first; of second; of third; of fourth; of fifth.

sponds with the unciform bone; on the radial side is a surface for the fourth metacarpal bone, and on the opposite side there is a prominence without an articular surface.

Heads. The *digital extremities* (*heads*) of all are convex, and articulated with the phalanges, the smooth surfaces extending farther on the palmar than on the dorsal aspect of the bones; on the sides are inequalities for the attachment of ligaments.

BONES OF THE FINGERS.

Phalanges; their number. These are fourteen in number; each digit, with the exception of the thumb, having three separate pieces (*phalanges, internodia*). Of these, the first is longer than the second, and the second than the third. Like other long bones, each is divided into a body and two extremities, of which one represents the base and the other the head. Winslow and some other anatomists reckon three phalanges in the thumb, as they conceive that its posterior, or most moveable bone, resembles the first phalanges of the other fingers, rather than the metacarpal bones. But if the bone of the thumb next the carpus be examined with attention, more especially its anterior extremity, and also its mode of articulation with the bone in front, it will appear to bear a more striking correspondence with the metacarpal range than with the first digital phalanges, and such is considered to be the case by Meckel, Portal, H. Cloquet, and J. Cloquet.

Has the thumb three phalanges?

The first row; The *bodies of the phalanges of the first row* are convex on the dorsal surface, and flat from side to side on the palmar, but arched from below upwards; the palmar surface is bounded by two margins which give insertion to the fibrous sheath of the flexor tendons.

form;

their terminal articular surfaces. The larger or *superior extremities* present each an oval concave surface, with its greatest diameter from side to side, which receives the convex head of the corresponding metacarpal bone. The *inferior extremities*, smaller than the others, end each in two small lateral condyles, with a slight groove between them,—both condyles and groove being adapted to the base of the contiguous bone, so as to form a ginglymoid, or hinge joint. The articular surface is prolonged farther on the palmar than on the dorsal aspect, which allows a more free range to the motion of flexion. The margins of the articular surfaces are rough and prominent for the attachment of ligaments.

The second row; The *second* or *middle row* consists only of four bones, inas-

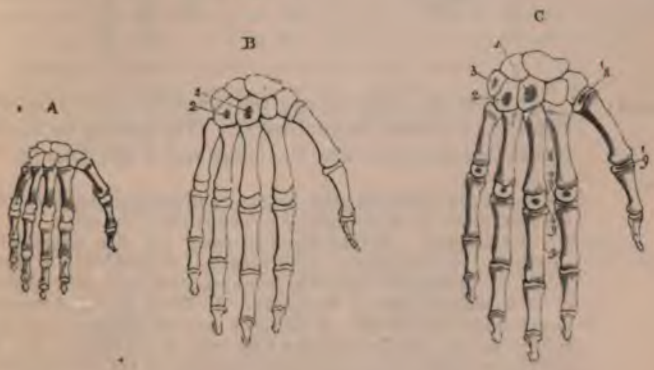
much as the two pieces which constitute the thumb correspond with the first and last phalanges respectively of the other fingers. Smaller than those of the preceding set, they still resemble them in their general outline. The broader, or superior extremity, ends in an articular surface, divided by a slight ridge extending from before backwards; the lateral parts being concave, for the reception of the two eminences on the contiguous bone. The inferior extremity is divided into two lateral convex surfaces, which are lodged in depressions in the base of the last phalanx. superior articular surface; inferior.

The *third row* (phalanges unguium) consists of five pieces, that of the thumb being the largest. They are convex on the dorsal, and flat on the palmar surface; rough at the summit, which corresponds with the point of the finger, and at the base, for the attachment of ligaments and tendons. The articular surface at the base resembles that of the base of the second phalanx, in having two shallow concavities separated by a central line. The third row; form; base.

OSSIFICATION OF THE CARPAL BONES.

The carpus is altogether cartilaginous at the general period of birth (fig. 57, A). In the course of the first year after, Condition at birth; one year after;

Fig. 57.*



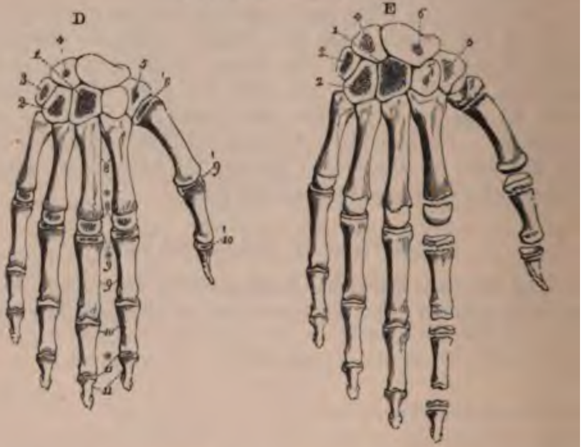
* A. The state of the various parts of the hand in a full-grown fœtus is shown in this figure. There is no osseous point in the carpus, but the metacarpal bones and the phalanges are ossified to a considerable extent. B. This figure represents the state of the bones about

ossification begins in the os magnum, and follows speedily in the unciform bone (B.$^{1\,2}$).

at three years; The pyramidal or cuneiform is the next to receive an osseous deposit, and this occurs in the third year (C.^{3}).

at five; In the fifth year nuclei are formed in the trapezium and semi-lunar; and as, at the end of that year, the nucleus in the former bone is the larger, it is to be inferred that it preceded the other in its growth (D.$^{4\,5}$).

Fig. 57 *(continued).*



at eight; At about six years of age the scaphoid, and, soon after eight, the trapezoid, begin to ossify. The granule for the first makes its appearance near the lower end of the bone (E.$^{6\,7}$).

the end of the first year after birth. C. shows their condition about the third year; D. at the fifth year; and E. about the ninth.

1. Os magnum. 2. The unciform bone. 3. The pyramidal or cuneiform. 4. Semi-lunar. 5. Trapezium. 6. Scaphoid. 7. Trapezoid. 8. Metacarpal bones—the principal piece. 8*. The epiphyses of the metacarpal bones of the fingers. 8′. The epiphysis of the metacarpal bone of the thumb. 9. The first range of phalanges; 9*. their epiphyses. 9′. Epiphysis of the first bone of the thumb. 10. The second row of phalanges. 10′. The epiphysis of the second bone of the thumb. 11. The last row of the phalanges; 11*. their epiphyses.

N.B. The carpal bones are numbered according to the order of their appearance, except the trapezium and semi-lunar, whose numbers have been accidentally transposed.—An appearance of ossification ought to have been shown in figure D. for the epiphyses of the second range of phalanges.

at twelve.

Lastly, the pisiform contains an osseous granule about the twelfth year.

Only one centre for each bone.

The carpal bones are formed each from a single centre. It may be observed that, in examining their condition during the first years of life, the relative periods at which their ossification begins, may, in a great degree, be determined by the comparative extent to which the deposit of bone has encroached on the pre-existing cartilages.

OSSIFICATION OF THE METACARPAL BONES.

Metacarpus.

Two centres for each bone.

Early period of ossification in body.

Epiphysis; its position and time of appearance.

Peculiarity of the first metacarpal bone.

The other parts of the frame-work of the hand differ widely from the carpus in the time at which their ossification commences, inasmuch as the process is far advanced in them before the end of fœtal life. Each metacarpal bone is formed from two parts, or from what may be considered a principal piece and an epiphysis. Its ossification begins in the middle of the body shortly after that of the bones of the fore-arm, and extends over the greater part of the bone, including its upper extremity (C. D.[8] E.) About the third year of age an osseous granule appears in the lower end, and the epiphysis resulting from its increase joins the principal piece before mentioned towards the twentieth year (C. D.[8*] E.). Such is the mode of construction of the metacarpal bones of the digits. The thumb differs from the rest in the position of the epiphysis, which is formed on the upper or carpal, instead of the lower extremity; whilst the lower end is produced by an extension from the principal piece of the bone (C. D.[8'] E.). And thus, in the manner of its growth, as well as in its shape, the metacarpal bone of the thumb assimilates to the phalanges.

OSSIFICATION OF THE BONES OF THE FINGERS.

Each has two centres.

These bones are likewise formed from two parts. The ossification begins about the same time as in the metacarpal bones; but it is stated by Meckel and others, that the primary nuclei do not appear in the bones of the second row for some time after they have been perceptible in those of the first and last. The osseous matter originating from each primary nucleus involves all the bone except its upper extremity.

Epiphysis; its position,

The additional piece or epiphysis begins to ossify at the third or fourth year in the first row, and a year later in the

period of appearance, and union. others;* and the bones are completed by the junction of their parts before the twentieth year (C. D. E.).

BONES OF THE LOWER LIMB.

Lower limb resembles upper in construction. The lower limb is connected with the hæmal arch (pelvic) of the thirtieth trunk segment or vertebra, and consists, like the upper limb, fig. 4, of three chief parts, viz., thigh, leg, and foot. In the bony framework of the arches and the limbs, there is also a very close resemblance, for in the haunch, which corresponds to the shoulder, is one large compound bone, the innominate; in the thigh is the femur; in the leg two bones, the tibia and the fibula; and in the foot are many bones in the tarsus, the metatarsus, and the phalanges.

INNOMINATE BONE. (OS INNOMINATUM.—OS COXÆ.)

The two bones which are distinguished by this appellation are of so complex and irregular a form, fig. 58, as to bear no perceptible resemblance to any other known object, and therefore remain "unnamed." They are situate at the inferior and lateral parts of the trunk, and extend from the sacrum forwards to the median line, where they are connected together, and form an osseous loop,—the hæmal arch of the second sacral vertebra, to which the lower limbs are hung.

Why named.

Forms pelvic arch.

Through the sacrum, which is wedged in between them, they receive the weight of the body from the vertebral column; and they transmit it to the lower extremities. Thus placed, and being somewhat curved in their general outline, they circumscribe the greater part of the cavity of the pelvis, the sides and fore part of which they form.

Office.

* The periods assigned by Béclard for the appearance of ossific granules in the epiphyses of the phalanges are as follows:—for those of the first range, three or four years; for the second or middle range, seven years; and for the last or ungual, four or five years.

Some preparations in my collection demonstrate that the time here connected with the appearance of bone for the epiphyses of the second phalanges cannot be generally correct. One case bearing on the point may be specially referred to, because no doubt could exist concerning the age, or the previously healthy state of the limb. I amputated the arm of a delicate female child, who on the day before the operation had attained the age of five years. The removal of the limb was rendered necessary in consequence of an injury. In the hand of this child the epiphyses of the three sets of bones of the fingers are advanced in ossification, and proportionally to the size of the cartilage, those of the ungual row appear the smallest.

With the view of rendering more intelligible the description of this very irregular bone, reference may be made to the pieces (fig. 59, c), into which it is found divided in early life. At that period the bone is composed of three parts, which meet together in the articular cavity, and to which the following names have been given: — the upper piece[1] is called iliac † (os ilium); the lower and hinder portion, ischial[2] (os ischii vel coxendicis, from ἰσχίον); and the anterior or remaining part[3] pubic (os pubis vel pectinis). After these pieces blend into one, the same nomenclature is still made use of in referring to parts of the bone, and in fixing the site of the several objects on it; thus a spine or a crest is distinguished by the prefix iliac, ischial, or pubic, according to its position on the upper, the lower, or the anterior part of the bone.

Nomenclature explained by growth.

Fig. 58.*

Names applied to primary parts.

Use of these when parts are joined.

The innominate is the largest of the class of tabular bones.

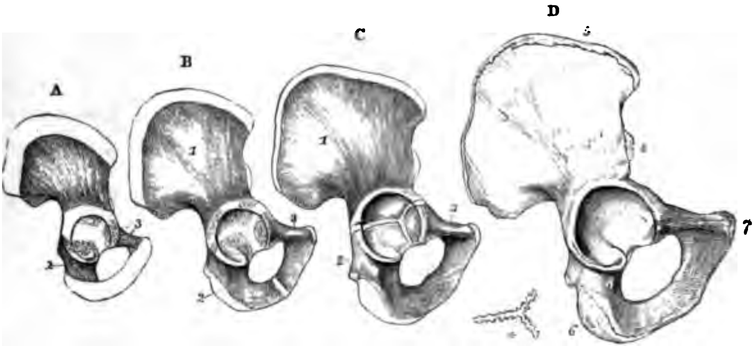
Size and shape;

* The innominate bone of the right side.—1. Dorsum ilii. 2. The superior curved line. 3. The inferior curved line. 4. Surface for the attachment of the gluteus maximus. 5. The iliac crest. 6. The anterior superior iliac spinous process. 7. The anterior inferior spinous process. 8. The posterior inferior spinous process. 9. The posterior superior spinous process. 10. A notch which forms part of the sacro-sciatic foramen. 11. The horizontal branch of the pubes. 12. The ilio-pectineal eminence. 13. The pubic surface, which goes to form the symphysis. 14. The angle of the pubes with its descending ramus. 15. Point of junction of the pubic and the ischial ramus. 17. A groove for the obturator externus. 18. Line to which the quadratus femoris is connected. 19. The ischial spine. 20. A smooth cartilaginous surface on which the obturator internus turns. 21. The tuberosity of the ischium. 22. Ramus of the ischium. 23. The acetabulum. 24. The brim of the acetabulum. 25. The notch of the acetabulum. 26. The depressed non-cartilaginous part of the acetabulum. 27. The thyroid foramen.

† Winslow states that this name is derived from the bone supporting the flank of the body, or the *ilia*. Exposition Anatomique, &c., § 676.

the fourth and fifth months the last of the principal centres of ossification is distinguishable in the horizontal branch of the pubic part.

Fig. 59.*



Condition at birth.

At the usual time of birth the deposit of bone has extended considerably from the primitive nuclei ; but the iliac crest is still largely cartilaginous, and the inner parts of the ischial and pubic pieces are in the same condition,—bony matter having at this period only begun to incline to the inner side of the thyroid foramen, fig. 59, A.

Rami of ischium and pubes join.

About the sixth year after birth, the ischial and pubic

* Some stages of the growth of the innominate bone are here exemplified.

Figure A. shows its condition in a full-grown fœtus. Ossification has extended from the primitive nuclei. But the crista ilii is largely cartilaginous ; the pubes and ischium are in the same condition at the inner side of the thyroid foramen, and a considerable cartilaginous interval separates the pieces in the acetabulum. B. This has been sketched from a preparation taken from a child under six years of age. Bony matter, spreading over the bone, has involved the inner parts of the ischium and pubes, but the osseous parts of their rami are still at some distance apart. C. The rami of the ischium and pubes are joined; a cartilaginous Y-shaped interspace is apparent in the acetabulum. D. This figure is from the body of a person aged about twenty years. Union has taken place in the acetabulum, and the epiphyses are fully formed.

1. Ilium. 2. Ischium. 3. Pubes. 4. Y-shaped piece. (This is a plan : this formation occurs in several fragments, which together would constitute a piece of this kind.) 5. Epiphysis of the crest of the ilium. 6. That for the tuber ischii. 7. For the pubes. 8. For the anterior inferior spine of the ilium.

rami are nearly altogether ossified (fig. 59, B), and they join about the tenth year (C).

The three divisions of the bone approach each other in the acetabulum, by the extension of the ossific process from the primary nuclei (fig. 59, A. B. C); and about the thirteenth or fourteenth year a distinct deposit of bony matter is observable in the cartilage which separates them in this situation. This added formation consists of several fragments; and, from the shape it necessarily assumes, it is named the Y-shaped piece. The union, therefore, of the iliac, ischial, and pubic parts occurs through the medium of the interposed piece or pieces now described, and it takes place after the usual time of puberty; the two first named joining in the first instance. Y-shaped piece in acetabulum, and junction of the principal pieces here.

About the age of puberty epiphyses begin to make their appearance as follows: Epiphyses, are four.

a. On the crest of the ilium, reaching over its whole length (D,[5]).

b. On the anterior inferior iliac spine (D,[8]). This epiphysis is not constant; it is said to occur more frequently in the male than in the female.

c. The ischial tuberosity becomes covered by a broad, curved crust, which reaches upwards on the ramus for some distance in a pointed form (D,[6]).

d. Lastly, the inner margin of the pubes receives a small epiphysary plate (D,[7]), which is stated by Béclard to be present more frequently in the female than in the male skeleton.

The epiphyses are all joined to the bone about the twenty-fifth year. Completion of the bone.

THE PELVIS.

The *pelvis*, or basin-shaped cavity, which is made up of the ossa innominata, the sacrum, and the coccyx, deserves to be attentively examined, not merely as to the details of the parts which compose it, but as to its general conformation. The pelvis.

The *external surface*.—Taking the objects which are deserving of notice on the external surface, and beginning at the median line in front, first is the *symphysis pubis*, or the point of junction between the two ossa pubis; its direction is nearly vertical, its depth greater in the male than in the female. Below it is an angular space, the *pubic* or *subpubic arch*, Its external surface; objects on it.

bounded by the rami of the ossa pubis and ischii of each side. On each side of the arch is the *thyroid* or *oval foramen* above noticed, and still more laterally is the *acetabulum*, above which rises the broad convex iliac part of the bone (dorsum ilii). Posteriorly, along the middle line, are situate the tubercles or spinous processes of the sacrum; external to these, the posterior sacral foramina; next, a broad, unequal surface, to which the sciatic and iliac ligaments are attached; and lastly, the large, deep excavation (*sacro-sciatic notch*), bounded by the margins of the sacrum and os innominatum.

Internal surface.

The *internal surface* is divided into two parts by a prominent line (linea arcuata), leading from the tuberosities of the ossa pubis, outwards and backwards, to the prominent point of the sacrum (*the promontory*). This constitutes the margin or *brim* or *inlet of the true pelvis;* all the part above it being called the *false pelvis*, from belonging in reality to the abdomen.

Divided into true and false pelvis.

Upper margin.

The *superior circumference* of the false pelvis is formed on each side by the crista ilii; posteriorly may be observed a deep notch, which is divided into two parts by the base of the sacrum, and anteriorly, (in the interval between the anterior-superior spinous processes of the ilia,) the margin of the pelvis subsides, so as to present a deep excavation, which in the natural condition is filled up by the soft parietes of the abdomen. Along this margin are placed the anterior inferior spinous processes of the ilia, the ilio-pectineal eminences, the spines or tuberosities of the pubic bones, with their cristæ and angles. The *inferior circumference* or *outlet of the pelvis* presents three bony eminences (the ischial tuberosities on the sides, and the point of the spine in the middle line behind), which are like so many promontories, separated by deep excavations. The anterior of these excavations (*pubic arch*), triangular in its form, is bounded on each side by the rami of the ischial and pubic parts, which extend upwards and inwards from the ischial tuberosities to the symphysis pubis. The two other notches (*sacro-sciatic*) are placed behind and above the ischial tuberosities, and correspond with the intervals between the sacrum and ossa innominata. When examined in the dried bones, their extent is considerable; but in the natural condition they are divided into smaller spaces by the sacro-sciatic ligaments.

Inferior margin or outlet.

Direction of

Obliquity of the pelvis.—In the erect attitude of the body,

the direction of the pelvis is so oblique (fig. 60) that the pelvic surface of the anterior wall (pubes) looks upwards as well as backwards, and that of the posterior wall (sacrum and coccyx) is directed downwards and forwards. At the same time the upper and lower apertures are inclined forwards. The base of the sacrum [2] is considerably higher than the

the pelvis is oblique.

Fig. 60.*

upper margin of the symphysis pubis; [1] the amount of excess varies in different cases, but in a large number of well-formed female bodies it has been found by M. Naegelé to be three inches and nine or ten lines. The point of the coccyx is stated by the same observer to be—taking the average of a large number of cases—seven or eight lines higher than the inferior margin of the pubic symphysis.† The obliquity of the pelvis is considerably greater in the fœtus and in the young child than in the adult.

Height of sacrum.

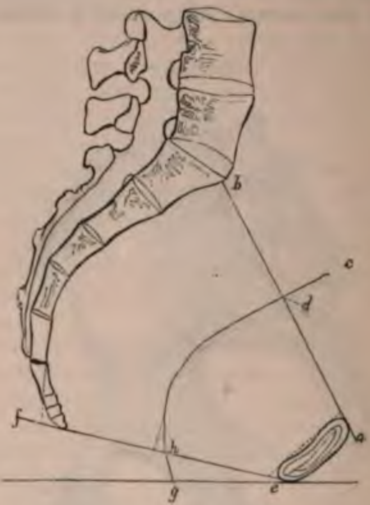
Most oblique in children.

* A vertical section of a female pelvis made through the symphysis pubis and the middle of the sacrum, and showing the left lateral half (reduced from Naegelé's figure). 1. Symphysis pubis. 2. Base of sacrum. 3. Coccyx. 4. Anterior superior spine of ilium. 5. Tuberosity of ischium. 6. Spine of ischium.

† M. Naegelé made observations on five hundred healthy females

The axis; *Axis of the pelvis.*—In determining a line which sh[...] be equally distant from the inner surface of the pelvis on [...]

Fig. 61.*



does not deviate laterally; curves in antero-posterior direction.

sides, it will be unnecessary to dwell on the lateral wall[...] inasmuch as these resemble one another exactly, and su[...] a line does not therefore in any degree deviate to either [...] them throughout the whole extent of the cavity. But there [...] so much difference between the anterior and posterior walls[...] the former 1½ to 2 inches in length, and oblique in directio[...]

who had borne children without the occurrence of unwonted difficult[...] one hundred and forty-nine of the number were tall persons, fifty-se[...] of short stature, and the remainder of middle height; he found

That the point of the coccyx was higher than the inferior margin of the symphysis pubis (the upper angle of the pubic arch) in	454
That it was lower than the same point in .	26
And that it was on the same level in . . .	20

The maximum of elevation of the point of the coccyx above the ap[...] of the pubic arch was twenty-two lines, and its maximum of depressi[...] below the same point nine lines. The average of all is stated in t[...] text.—"Das weibliche Becken," &c. Carlsruhe, 1825.

* A vertical section in outline of the pelvis at its middle, with lin[...] indicating the axes of the pelvis, and a horizontal line below the figur[...]

the latter about 5 inches long, likewise oblique and much curved,—that the axis will be situate at different distances from these walls in different parts of the cavity. It is for this reason that several axes, or axes for several parts, are recognised; viz. one for the inlet of the true pelvis, another for the outlet, and another again for the intervening space,—the cavity; and each of these requires some notice. It must be premised, that the direction of the axis at any part of the cavity will be marked by a line which is at right angles with, and passes through the centre of the plane of that part.

Three axes.

The axis of the inlet of the true pelvis.—The plane of the inlet of the true pelvis will, in the section of the cavity (fig. 60), be represented by a line drawn between the base of the sacrum and the upper margin of the pubes (fig. 61, *a b*), and a line at right angles with this at its middle, *c d*, will give the direction of the axis required. The axis of this part is therefore directed downwards and backwards, and is usually said to coincide with a line drawn from the umbilicus to the lower part of the sacrum; and this is not far removed from correctness, for M. Naegelé found that in the average of a large number of female pelves the lower end of such a line would fall against the coccyx (below the middle). As regards the *axis of the outlet*: it is indicated by the line *h g*, at right angles with *e f* at its middle, which line represents, in the section, the plane of this part of the cavity. This axis is, therefore, directed downwards and forwards; and if continued into the cavity, would cross an extension of the axis of the inlet. When the coccyx is moved backwards, this axis undergoes a corresponding alteration, as indicated by the dotted lines behind *h*.

Axis of inlet, downwards and backwards; of outlet, downwards and forwards;

The axis of the cavity.—The cavity of the pelvis being much curved, so likewise must its axis be; and for general purposes it will be sufficiently correct to say that, beginning with the axis of the inlet, and following the curve of the sacrum and coccyx in the middle of the cavity, it terminates in the axis of the outlet—in the course of the curved line between *d* and *h*.*

of cavity, curved between two former.

It is to be borne in mind that the foregoing observations have reference to the pelvis in the skeleton, its osseous

* The exact course of the line may be determined by finding the axes of different parts of the cavity, situate at very short intervals below each other, on the principle already referred to, and drawing a line through them.

Ossification.

The patella is ossified from a single centre, which, according to Béclard, is apparent in the middle of the third year.

THE TIBIA.

Tibia, its size; direction.

The tibia, next to the femur, is the longest bone in the skeleton. Situate at the anterior and inner side of the leg, it alone receives from the femur (under which it is placed vertically) the weight of the trunk, and communicates it to the foot. Like the other long bones, it is divided into a body and two extremities.

Its superior extremity.

The *superior extremity* (fig. 64,[1]), much thicker and more expanded than any other part of the bone, since it is proportioned in size to the lower extremity of the femur, is broader from side to side than from before backwards; its circumference is somewhat rounded and convex in front and at the sides, but slightly hollowed posteriorly. At the forepart, a little below the head, is an eminence,[2] the *tubercle*, which is somewhat rough at its lower part, for the attachment of the ligament of the patella; and smooth superiorly, where it corresponds to a small synovial bursa, intervening between that ligament and the bone. On the sides of the bone, and above this tubercle, are two rounded eminences, the *tuberosities*, the external one [3] being somewhat smaller than the other,[4] and marked posteriorly by a flat surface which articulates with the head of the fibula. On the superior aspect of this portion of the bone may be observed two concave cartilaginous surfaces,[5] [6] the *condyles*, which sustain the condyles of the femur; the internal one is somewhat the deeper, and its greatest diameter is from before backwards; the external one is nearly circular. In the interval between the articular surfaces is a pyramidal eminence,[7] the summit of which is usually divided into two tubercles; it is named the *spine* or *spinous process* of the tibia; both before and behind this is an irregular and depressed surface, which gives attachment to the crucial ligaments and the semilunar cartilages.

Tubercle.

Lateral tuberosities.

Condyles.

Spine.

Fig. 64.

which may be said to belong to the pelvis, lie chiefly in the abdomen. The obliquity of the cavity is greatest in early life. liquity of pelvis in early life.

THE FEMUR.

Femur, its size;

The femur or thigh-bone (fig. 62; *os femoris*), the longest and largest bone of the skeleton, is situate between the pelvis and the tibia. In the erect position of the body, its general direction is not vertical, but gradually inclined inwards towards the lower part; so that the bones of opposite sides, though at a considerable distance apart where they are connected with the pelvis, approach each other inferiorly, and come nearly in contact. The degree of this inclination varies in different persons, and is more marked in the female than the male. The femur presents a central part or body, and two extremities.

oblique direction.

Fig. 62.*

Shaft;

The *body*,[1] or the *shaft* as it is sometimes called, compressed, but nearly cylindrical towards the centre, and at the same time slightly convex or arched forwards, is expanded superiorly and inferiorly. Its anterior surface, convex and smooth, is broader towards the lower than the upper end. Both its lateral surfaces are compressed and somewhat flat; but it may be observed that the external is somewhat concave. The surface, which superiorly looks inwards, is, in the lower third of the bone, inclined somewhat backwards, and gives attachment to the vastus internus. The anterior surface is separated, though not in a very marked degree, from the lateral surfaces by two lines, which may be traced upwards from

its surfaces.

* A front view of the femur of the right side. 1. The shaft. 2. The great trochanter. 3. The small trochanter. 4. The neck. 5. The head. 6. is above the trochanteric fossa. 7. is said to mark the external condyle. 8. The articular surface of the external condyle. 9. A pit for the tendon of the popliteus muscle. 10. The external tuberosity. 11. The internal condyle. 12. The internal tuberosity.

the condyles, towards the superior extremity of the bone; but posteriorly, at the union of the two lateral surfaces, is a rough and prominent line, the *linea aspera*, which gives attachment to several muscles.

Linea aspera;

The *linea aspera* is most prominent towards the centre of the bone, and, when examined with attention, presents two margins and a rough interval, each giving attachment to muscles. Above and below the centre, it subsides as it were towards the extremities, and also becomes bifurcated.

its branches, upper and lower.

The two superior divisions or branches of the line terminate, the one (internal and somewhat shorter) at the lesser trochanter; the other, external, at the greater trochanter; in the course of the latter a rough and often strongly-marked impression exists, which gives insertion to the gluteus maximus. The inferior divisions spread more asunder, and terminate at the condyles, enclosing with the margins of these prominences, a flat triangular portion of the bone, which corresponds with the popliteal vessels. Towards the

Nutritive foramen.

superior part of the linea aspera may be observed a foramen, directed from below upwards, which transmits nutritive vessels of the shaft.

The upper end of bone; its direction.

At the *superior extremity* of the bone is placed its neck, which is directed upwards and inwards, so as to form an obtuse angle with the body or shaft; at its point of union with the latter are two eminences (trochanters), one the larger on the outer, the other on the inner side; it is from between these that the neck arises.

Great trochanter.

The *trochanter major*[2] is prolonged from the external surface of the body of the bone, and nearly in a line with its axis. This apophysis, quadrilateral in its form, is convex and rough on its external surface, which is impressed with a mark directed obliquely downwards and forwards for the attachment of the gluteus medius; the internal surface,

Trochanteric fossa.

of less extent, presents at its base a pit,[6] the *trochanteric* or *digital fossa*, which gives insertion to the external obturator muscle; its superior, or terminal border, is flat and straight, and the posterior thick and rounded. At the posterior aspect of the great trochanter may be observed an oblique and prominent line, directed downwards and inwards, and terminating in the trochanter minor.

Small trochanter.

The *trochanter minor*[3], a conical rounded eminence, projects from the posterior and inner side of the bone, and gives attachment at its apex and back part to the tendon of the psoas muscle.

The *neck* of the femur,[4] which is so named from its constricted appearance and supporting the head, forms an obtuse angle with the body of the bone, and is pierced by numerous vascular apertures, especially at the back. It is compressed from before backwards, so that its diameter is much less considerable in this than in the vertical direction, in which greater power of resistance is required for sustaining the weight of the body; its anterior surface is broad and smooth; the superior border, inclined upwards, is short and somewhat concave; the inferior is the most extensive. The union of the neck with the body of the bone is marked by the trochanters and two intervening oblique lines, *inter-trochanteric*, of which the anterior one is rough, and but slightly prominent; the other, situate posteriorly, forms a smooth projecting ridge, which overhangs the trochanteric fossa. The neck.

Inter-trochanteric lines.

The neck is surmounted by the globular *head*,[5] which forms a considerable segment of a sphere, is coated with cartilage in the fresh state, and lodged in the acetabulum. A little below its most prominent point is a small pit, which gives attachment to the round ligament. The head.

The *inferior extremity* of the bone, much thicker and broader than the superior, is terminated by two eminences, separated posteriorly by a deep fossa; these are named condyles, of which one is external, the other internal. The lower end of bone.

The *external condyle*[7] is larger, and projects forwards more than the internal; its articulating surface also is broader, and mounts higher up anteriorly; its external surface, rough and unequal, presents inferiorly a pit,[9] which is elongated from before back, and gives origin anteriorly to the tendon of the popliteus muscle; immediately above this is a projection,[10] *external tuberosity*, which gives attachment to the external lateral ligament of the knee-joint. External condyle. Pit for popliteus. External tuberosity.

The *internal condyle*[11] is the longer, and descends rather lower down than the other; but by means of the obliquity of the shaft of the bone, both condyles are brought to the same level when the femur is in its natural position. The internal condyle projects from the axis of the bone more than the external one; it presents at its inner side *a tuberosity*,[12] which gives attachment to the internal lateral ligament of the knee-joint and the tendon of the adductor magnus. Internal condyle. Internal tuberosity.

The *articular surfaces* of both condyles, covered with cartilage in the fresh state, are united anteriorly, where they form a pulley-like surface[8] concave from side to side, on Articular surfaces.

inwards towards that bone. Like the tibia, it is divided int a body and two extremities.

Shaft; its three borders; The *body* or *shaft* of the bone, irregularly triangular in it form, presents three prominent lines bounding three surfaces the anterior (fig. 64,[15]) or most prominent line bifurcate towards the lower extremity of the bone, so as to enclose slightly concave triangular surface,[16] which is subcutaneous The internal one also gives attachment to muscles, and infe riorly, where it inclines forwards, the inter-osseous ligamen is inserted into it. **internal surface;** The *internal* surface[17] looks backwards fo about a third of its extent, and somewhat forwards in the rest and is divided, but unequally, into two parts by a slightly **ridge for inter-osseous ligament;** marked longitudinal line, to which the inter-osseous ligament is chiefly attached: the part of the surface behind this line i grooved, and presents a vascular opening, directed down **foramen for vessels;** wards, for the chief bloodvessels of the shaft of the bone it gives attachment to the tibialis posticus muscle: th anterior portion, the smaller, affords attachment to muscle **external surface;** placed on the front of the leg. The *external* surface,[18] concave in the greater part of its extent, gives origin to muscles Towards the lower end of the bone this surface is incline backwards, conforming with the peronei muscles, which ar connected with it, and incline in that direction to pas **posterior surface.** behind the external malleolus. The *posterior* surface flattened and rather smooth, affords attachment to muscles in the lower part it inclines inwards, and is terminated by rough surface connected with the tibia.

The head. The *superior extremity* of the bone,[19] called also *the head*, is smaller than the inferior one; it presents on the supero-internal part a small oval and nearly flat surface, for its articulation with the corresponding part of the external tuberosity of the tibia; the remainder is uneven, and gives insertion to the biceps flexor cruris, and to ligaments. The **External malleolus;** *inferior* or *tarsal extremity*[20] forms the *external malleolus*, which is longer and more prominent than the internal one; in front it projects rather abruptly forwards; behind is a shallow groove traversed by the tendons of the peronei **is subcutaneous.** muscles; the outer side is convex and subcutaneous; the inner presents a small triangular surface, convex in the per-pendicular, and nearly plain in the antero-posterior direction, which articulates with the astragalus, and is bounded pos-teriorly by a rough depression, affording attachment to a ligament of the ankle-joint; the apex gives origin to part of the external lateral ligament.

Articulations.—The fibula articulates at both extremities with the tibia, and at the inferior one with the outer surface of the astragalus. **Articulations.**

The ossification of the shaft of this bone occurs a little later than that of the shaft of the tibia. Both ends are cartilaginous at the ordinary time of birth (fig. 66, A). **Ossification. State at birth.**

The epiphyses are likewise formed after those of the tibia. Their ossification begins with the lower one, in which an **Epiphyses; lower and upper.**

Fig. 66.*

osseous granule appears in the second year (B,[2]); and the commencement of the process is discernible in the upper epiphysis, between the third and the fourth year (C,[3]).

Consolidation.—Contrary to the order which prevails in the union of the parts of the femur and the tibia, that epiphysis of the fibula, which is the first to take on the osseous state, namely, the lower and larger one, is at the same time the first to join the shaft of the bone (D). The **Order of their junction is peculiar.**

* A. The preparation from which this figure has been drawn was taken from the body of a fœtus arrived at the usual period of birth. The shaft is ossified, and the ends of the bone remain cartilaginous. B. A nucleus has appeared for the lower epiphysis. C. That of the upper one is added. (When the upper epiphysis is ossified to this extent, the lower one is more advanced than is here represented.) D. The lower end of the bone is complete, the superior epiphysis being still separable.

1. The shaft. 2. The lower epiphysis. 3. The upper one.

Completion. parts appear to unite somewhat later than in the tibia; the consolidation is complete between the twentieth and the twenty-fifth year.

BONES OF THE FOOT.

The foot; its divisions. The foot is composed, like the hand, of three parts, viz. the tarsus, the metatarsus, and the phalanges; their upper and under aspects are shown in figs. 67 and 67*. These parts will in the first place be described separately, and they will then be reviewed in connection one with another, constituting the frame-work of the foot.

TARSUS.

Tarsus; its composition. The tarsus is composed of seven bones, viz. the os calcis, astragalus, cuboid, scaphoid, and three cuneiform.

THE CALCANEUM.

Os calcis forms the heel.

Fig. 67.

This bone, fig. 67, (os calcis—calcaneum,) is placed at the posterior and inferior part of the tarsus, and forms the heel by its projection backwards; elongated from before backwards, and compressed laterally, it is the largest of the bones of the foot.

Articular surfaces for astragalus, and groove between. *Superiorly* it presents (taking the objects successively from behind forwards) a concave portion,[1] intervening between its posterior border and the surface which articulates with the astragalus; then the last-named surface, which is bounded anteriorly by a rough depression for the insertion of a ligament (interosseous); and lastly a narrow concave surface,* which also articulates with the astragalus.

Inferior surface and tubercles. On the *inferior surface*, which is narrower than the preceding, and broader behind than before, are observed posteriorly two tubercles,[2 3] (the internal being the larger,) serving for the attachment of the

* This is sometimes transformed into two surfaces, which vary in their shape and size.

plantar fascia and the superficial plantar muscles; and between them is a depression for the origin of the long plantar ligament. Near the front is another eminence,[4] giving attachment to the inferior ligament (calcaneo-scaphoid) connecting this bone with the scaphoid.

Fig. 67*.

Anterior and posterior surfaces.

The *anterior surface*, the smallest, is slightly concave, and articulates with the cuboid bone. The *posterior surface*, convex, forms a rough projection inferiorly (*tuber calcis*),[5] which receives the attachment of the tendo Achillis, and is continued into the tubercles on the lower surface of the bone,[2 3] more especially the inner one. The upper part of the posterior surface,[6] smooth and less prominent, is separated from the tendo Achillis by a synovial bursa.

Tuber calcis; attachment of tendo Achillis.

External surface, partly subcutaneous.

The *external surface*, nearly flat, broader behind than before, presents towards the forepart superficial grooves[7] for the tendons of the peronei muscles, and is subcutaneous in the rest of its extent.

Internal surface deeply concave.

The *inner surface*,[8] deeply concave, is traversed by the plantar vessels and nerves, and the tendons of the flexor muscles. At the anterior and upper part of this surface is a prominent process, which deepens the concavity; it is grooved beneath[9] for the tendon of the flexor longus pollicis, and above contributes to form the concave articular surface which supports the forepart of the astragalus, and hence the name "sustentaculum tali" applied to it.*

Sustentaculum tali.

Articulations.

The calcaneum articulates with the astragalus and the cuboid bone.

THE ASTRAGALUS. (TALUS.)

Astragalus.

The astragalus (ἀστράγαλος, a die,) is the highest bone of the tarsus; its form is irregular, and it appears as if twisted on itself.

Upper surface.

The *upper surface* presents, in front, a rough and slightly excavated part,[10] serving for the attachment of ligaments;

* Or "sustentaculum cervicis tali."—"Albini de sceleto humano liber." p. 302.

Articular surface for tibia; its peculiar form; those for malleoli, their difference.

and behind this a large convex cartilaginous surface [11], which is more prominent on the outer than on the inner side, broader before than behind, and articulated with the lower extremity of the tibia. On both the *outer* and *inner sides* is a smooth surface,[12 13] (the outer triangular and the deeper); these surfaces are continuous with the preceding, and articulated with the inferior extremities of the tibia and the fibula—the *malleoli*. On the *inferior surface* are observed, in front and somewhat internally, a narrow flattened surface, and behind a broad concave one, both articulating with the os calcis; these are separated by a groove which receives the ligament that proceeds upwards from the last-named bone. The *anterior surface*,[14] convex, is received into the hollow in the scaphoid bone; it is called the *head*, and the constricted part by which it is supported, the *neck* of the astragalus. The *posterior surface*, or rather border, is grooved and traversed by the tendon of the flexor longus pollicis.

Those for os calcis separated by groove. Head. Neck. Groove for tendon.

Articulations.

The astragalus articulates with the tibia and the fibula above, with the os calcis below, and with the scaphoid in front.

THE CUBOID BONE.

Cuboid; its position.

This bone (*os cuboides, cuboideum*) is situate at the external side of the tarsus; its form is indicated by its name.

The *superior surface*,[15] rather rough, and inclined obliquely outwards and upwards, gives attachment to ligaments. The *inferior surface* presents in front a depression,[16] traversed by the tendon of the peroneus longus muscle; in the middle a transverse ridge (tuberosity),[17] and behind this an irregular surface,[18] both of which give attachment to the calcaneo-cuboid ligament, and the former also to some fibres of the ligamentum longum plantæ. At the *anterior aspect* of the bone is a smooth surface, which is divided into two parts, the internal one being square, the external triangular,—the former articulating with the fourth, the latter with the fifth metatarsal bone; at the *posterior aspect* is a surface for articulation with the os calcis. The *external surface* or rather *border* is short and rounded, and presents a groove,[19] which is continuous with that on the inferior surface, and serves for the transmission of the tendon of the peroneus longus muscle. On the *internal surface* may be observed, towards its middle, an elongated, smooth, and nearly flat portion,[20] which articulates with the third cuneiform bone, the part before and behind it being rough for the attachment of ligaments.

Ridge on lower surface. Anterior part divided. Short external border. Lateral articular surfaces.

This surface likewise articulates sometimes with the scaphoid by a smaller posterior impression.

Articulations. The cuboid articulates with the fourth and fifth metatarsal bones before, with the os calcis behind, with the external cuneiform, and sometimes with the scaphoid.

THE SCAPHOID BONE.

Scaphoid; its position. The scaphoid or navicular bone,[21] so named from its excavated form (σκαφη, *navis*), is placed at the inner border of the foot, between the astragalus and the cuneiform bones.

Tubercle at inner side. Concave articular surface. Facets for three cuneiform bones. It presents a concave articulating surface which looks backwards, and a convex one which is turned forwards. Its inner margin projects in the form of a tubercle[22] towards the sole of the foot. Upon its upper and inner surfaces are inequalities for the attachment of ligaments; behind, a concavity for the head of the astragalus; in front, three distinct surfaces for articulation with the three cuneiform bones. At the lower and inner border is the prominence or *tubercle*, above noticed, which gives attachment to the tibialis posticus muscle; on the outer side, in some instances, is a small articular surface, by which it is united to the cuboid bone.

Articulations. It articulates with the three cuneiform bones, with the astragalus, and sometimes with the cuboid.

THE CUNEIFORM BONES.

Three cuneiform; These bones[23 24 25] (ossa cuneiformia, wedge-shaped) constitute the anterior and inner part of the tarsus; the name expresses their form. In number three, they are distinguished by their numerical order from within outwards.

their differences. Articulations. The first is the largest, and has its base or broad portion turned downwards to the sole of the foot; whilst the second, or middle one, is the smallest. The second and the third have their bases or broad parts at the upper or dorsal surface of the foot, and contribute to give it its arched form. These bones articulate behind with the navicular, and in front with the first, second, and third metatarsal bones. In consequence of their excess in length over the middle one, the outer and inner, in addition to articulating laterally with the corresponding sides of that bone, are in apposition with the base of the second metatarsal bone, which is inserted between them. The inner side of the first is subcutaneous, and the outer

side of the third articulates, by a smooth flat surface with the cuboid, and by a small linear facet with the fourth metatarsal bone.

METATARSAL BONES.

Metatarsal bones; number; inter-osseous spaces.

The metatarsus, the second division of the foot, is placed between the tarsus and the phalanges of the toes, and consists of five bones, one for each toe. These are separated, except at their posterior extremities, where they are in contact, by four interspaces (*inter-osseous spaces*), which decrease in size from the inner to the outer side of the foot. The bones are named according to their numerical order from within outwards—that of the great toe being the first, and that of the little toe the fifth or last; and the inter-osseous spaces are named in a similar manner.

Characters.

Common characters of the metatarsal bones.—They are long bones in miniature, and may therefore be conveniently regarded as consisting each of a body and two extremities.

Bodies, triangular.

The *bodies* are, in the longitudinal direction, somewhat concave on the plantar and convex on the dorsal aspect; and they have each, with more or less regularity, three sides and as many borders. One side corresponds with the dorsum of the foot, and the others bound the inter-osseous spaces.

Bases, wedge-shaped.

The *posterior* or *tarsal ends* (*bases*) of these bones are broad and squared on the dorsal surface, and, becoming narrower in the opposite direction, they contribute, in consequence of their cuneiform or wedge shape, to the general transverse arching of the foot. They terminate behind with plane articular surfaces for connection with the tarsal bones; and, with exceptions to be noticed presently, they have likewise small articular faces on their sides, where they are in contact one with another.

Heads, smaller; their articular surfaces.

The *anterior* or *digital ends* (*heads*) of the metatarsal bones are slightly apart from each other, and are marked on their sides by depressions and by small tubercular projections. They are much smaller than the tarsal extremities, and they support the first phalanges of the toes by convex articular surfaces, which extend on to the plantar aspect of the bones—the aspect of flexion of the joints.

Each has distinctive characters.

While the metatarsal bones thus resemble one another in some respects, or have certain characters in common, each

has peculiarities which serve to distinguish it from its fellows.

Special or individual characters.—The great size of the *first* is its most prominent distinctive mark. It is much thicker, and more massive, though shorter than any of the other bones. The tarsal end, or *base*, rough at its circumference, especially towards the plantar aspect, has no lateral articular facet, and wants the square shape which belongs to the others. The surface which rests against the first cuneiform bone is oval and slightly concave; and the joint formed between them is directed obliquely forwards and outwards. The digital end (*head*) forms the ball of the great toe: it is in contact on the plantar aspect with two sesamoid bones; the articular surface appropriated to these little bones is divided by a ridge into two parts, one for each bone: these parts, either one or both, often have a grooved form.

First; its size; no articular surface on sides.

The *second* is the longest of the metatarsal bones. The posterior end has articular surfaces for the three cuneiform bones—it rests against the second, and is supported laterally by the first and the third. On the outer side it is likewise articulated with the third metatarsal.

Second is the longest; articulates with three tarsal bones.

The distinction between the *third* and the *fourth* is by no means so readily made as between others of the series. They have nearly the same length, but the third is slightly the longer. Moreover, the lateral articular surface on the inner side of the fourth is not so close to the tarsal end of the bone, as it is on the neighbouring side of the third; from this it results, that, when the two bones are adapted to each other in their proper relative position, the fourth projects behind the third; and this is necessary, in order that it should reach the cuboid, whose articular surface is in a corresponding degree behind that of the third cuneiform bone. It will likewise usually be found that the fourth has on its inner side, for connection with the tarsal bone last mentioned (third cuneiform), a small additional facet, which would serve to characterise it.

Third and fourth distinguished.

The *fifth* is readily recognised by several striking characters, viz. its length (which is less than that of any of the other metatarsal bones except the first), the large size of its base, and some further peculiarities of this extremity: namely, the presence of a single lateral articular surface for the fourth metatarsal bone, and a large rough tuberosity on the opposite side, which projects beyond the other

Fifth, its length; tuberosity.

is the pleurapophysis (fig. 2, pl. ap.); this is represented by the scapula proper in one loop, and by the iliac piece of the haunch-bone in the other. The next component, in the order named, is the hæmapophysis, (h. ap.)—its counterpart being the coracoid process or bone in the scapular arch, and the ischial bone in the pelvic. The last element, completing a visceral arch, is the hæmal spine, (h. s.); but this is not supposed to be present in either of the two arches, since they are not joined by bone across the middle line of the body, but are connected only by ligamentous structure.

scapula with ilium;

coracoid with ischium;

and clavicle with pubes.

The determination of the nature of the remaining pieces of the scapular and pelvic arches, viz. the clavicle and the os pubis, is somewhat less easy. Without entering fully into this debated point, we may say, that they are considered to belong to the hæmal arches of other segments—the former to the first cervical, and the latter to the first sacral vertebra. According to this view, they are hæmapophyses of those segments, which are enlarged, and contribute in man to form the loops for the support of the limbs.*

Resemblance of femur and humerus obvious.

Arm and thigh bones.—Alike as far as concerns their position in the limb, and their use, the arm and the thigh bones further resemble one another closely in form. Rounded in the shaft, each has at one end a spheroidal head, with a neck not in a line with the shaft, and two tuberosities or levers for the attachment of muscles; and at the opposite end, each, being elongated transversely, is furnished with condyloid articular surfaces.

Two bones in each limb.

Bones of the fore-arm and leg.—In both limbs there are two bones, and anatomists have differed much respecting the question, which two of the four bones correspond to one another. In determining this matter the size and shape of the bone, and its upper articulation, are not so important to be considered as its position in the limb, and specially its articulation with the hand or the foot.† Keeping in view these points, we observe that the radius in the fore-arm is placed on the same side of the limb as the thumb, whilst the tibia is, in like manner, in a line with the great or inner toe, and it might appear from this circumstance, that these are the two answerable bones: but as the hand can at one time be

Radius and tibia

* The view can be here stated only shortly, but the reasons for its adoption are given by Professor Owen in his published works "On the Homologies," and "On the Nature of Limbs."

† This identification is easier when the condition in animals is taken into account.

flexor muscles (the only exception to this statement being the patella), and serve the purpose of increasing their mechanical advantage, by removing them farther from the axes of the bones on which they act.

BONES OF THE FOOT AS A WHOLE.

The osseous framework of the foot, constructed of the parts above separately described—tarsus, metatarsus, and phalanges of the toes—is placed horizontally below the leg which rests on its upper surface. The foot.

The posterior end (the heel), projecting behind the leg, is narrow and thick; the anterior part is broad, thinner, and expanded towards the toes. The upper surface ("dorsum" of the foot) is convex in two directions—longitudinally and from side to side. But in the latter direction the arch of the foot is much higher at the inner than at the outer side; and it is towards the inner and more arched, which is at the same time the longer and more massive side, that the weight of the body is received from the leg. The lower or plantar surface (sole of the foot) presents corresponding concavities. From this shape it results, that, when the foot rests on a flat surface, the heel, the digital ends of the metatarsal bones, the toes, and the outer part of the sole are in contact with the surface; but the middle, especially towards the inner side, is elevated from it. Heel. Dorsum, convex in two directions. Plantar surface concave.

The constituent elements of the hand and the foot are adapted by differences in their size, and in their relative proportion and arrangement, to the very different uses of the limbs to which they respectively belong. Foot contrasted with hand.

Thus, all the parts of the upper limb, which is a prehensile organ, are in a line one with another; the fingers are elongated, and comparatively free from the palmar part; and the thumb (including its metacarpal bone) has independent motion, and may be opposed to the other fingers. At the same time the carpus is small, serving only to connect the metacarpus to the bones of the fore-arm, and to contribute to the free motion of the wrist. On the contrary, the foot, an organ of support, is set on at right angles with the leg, and has no provision for the variety and facility of motion which belong to the upper limb. The toes, small in size, are cushioned at their roots by the soft parts of the sole of the foot, in which they are impacted; the great toe has only the same extent of movement as its fellows; and the Upper limb prehensile. Lower limb for support.

limbs differ in number and position.

three in the foot; but practically it may be said to have the same number in each, as the pisiform is out of the range in the hand, and appears more like a sesamoid bone. Taking the number then as the same, the arrangement in the hand is transverse as in the anterior row; but in the foot, on the contrary, the bones are placed in a line from before backwards, so as to elongate the part supporting the body. The inner bone of this row in the hand (which is still supposed prone) and the anterior one (scaphoid) in the foot articulate with corresponding bones in the anterior rows; whilst the external bone in the hand (omitting the pisiform) and the hinder one in the foot (os calcis) articulate respectively with the homotypal bones in the anterior rows; the middle bone in each instance maintaining its connection with the inner long bone (radius, tibia) of the fore-arm and the leg. By the connections it is determined that the representative parts in the hinder row in the two limbs are, scaphoid of the hand and scaphoid of the foot; semilunar in the upper, and astragalus in the lower extremity; and the conjoined cuneiform and pisiform and the os calcis—the epiphysis at the back of the latter being the counterpart of the pisiform bone.

Articulations of hinder with anterior set.

Correspondence of bones of hand with those of foot.

Middle bone in both rows keeps its place.

Although the arrangement of the bones of this group is so much altered in the foot, the middle one of the three, the astragalus, keeps its relative position; but being greatly enlarged it pushes forward, so to say, the scaphoid, and backwards and downwards the os calcis, and comes to occupy alone the whole articular surface of the tibia.

Counterparts in digits;

Metacarpus, metatarsus, and phalanges.—The correspondence of the bones of the different digits of the two members, is too apparent to require explanation; the thumb being to the hand what the great toe is to the foot, the little or fifth toe answering to the little finger; and so on through the whole series. It is worthy of observation that the middle digit—the most permanent ray in the divided extremity of the appendage in different beings—exceeds the others in length in both limbs of man.

middle one longest.

Limbs made on a like plan,

The several points of similitude between the upper and lower members, which have been adduced, make obvious the fact, that these appendages of the body are constructed on the same plan, only minor modifications having been impressed on the constituents to suit them to the different functions the limbs have to perform,—in the one instance to minister to the wants of the body, and in the other

but modified for use.

to support and convey the massive trunk over the surface of the ground.

MAN ADAPTED TO THE ERECT POSTURE.

Lower limb props body.

Every part of the human body indicates by the conformation its adaptation to the erect position. The feet are broader than those of any other animal proportionally to its size; the tarsal and metatarsal bones admit of very little motion; and the great toe is on the same plane with the others, and cannot be brought into opposition with them. The foot is thus fitted to sustain the weight of the body, but not to grasp or seize objects presented to it. The hands, on the contrary, though so well adapted for these purposes, are ill calculated for affording support; so that man is truly "bimanous" and "biped." * The tibia rests perpendicularly on the astragalus, and the os calcis projects backwards for the purpose of increasing the base, and also of lengthening the lever to which the strong muscles of the calf of the leg are attached. The whole extent of the tarsus, metatarsus, and phalanges, in man, rests on the ground, which does not obtain even in apes, the end of whose os calcis is somewhat raised, so as to form an acute angle with the bones of the leg. In dogs and digitated quadrupeds, the carpus and tarsus are considerably elevated from the ground, so that the body rests on the toes; and in the horse, and other solid-hoofed animals, the third phalanges only rest on the ground, the os calcis being raised nearly to the perpendicular direction.

How differs in quadrupeds.

Femur adapted for a pillar of support.

The femur, placed securely beneath the pelvis, affords a firm support during progression. The great breadth of the pelvis serves to enlarge the base on which the trunk rests; and this is farther increased by the length of the cervix femoris. This peculiarity in the neck of the femur renders it necessary that the body of the bone should be inclined inwards towards the median line, in order that it should support effectually the centre of gravity. If its articular head be viewed in profile, it will be observed that the cartilaginous coating is distributed for the most part on the upper and inner aspect, showing its adaptation as a pillar of support in the erect position.

Pelvis supports viscera.

The bones of the pelvis in the human being are distinguished from those of other animals by some marked peculi-

* Règne Animal., tom. i. p. 82.

arities. The sacrum is remarkably broad and expanded, so as to form a firm support for the spinal column, which rests upon it; its lower part is curved and articulated with the coccyx, so that both incline forwards and assist to enclose the pelvic cavity, constituting a support for the viscera when pressed down by muscular action. If a different arrangement of these bones obtained—if they were continued downwards in a straight line, they would project beyond the ischia, and render the sitting posture irksome or impossible.

Spinal column sustains weight.

The spinal column, which supports all the other parts, is peculiarly adapted to the erect attitude. Its pyramidal form and enlarged base fit it to sustain the superincumbent weight; and by means of the different curvatures which it presents, a considerable range of motion is allowed to the trunk, the centre of gravity being still supported within the base. The form of the thorax is also peculiar. Shallow and compressed from before backwards, it is broad and expanded from side to side; by which means the preponderance of the trunk forwards is considerably lessened. The sternum, though broad, is very short, so that a considerable space intervenes between it and the pubes, which is occupied solely by muscular parts. But in quadrupeds, the thorax is compressed and flattened laterally, becoming gradually narrower towards the sternum, which is prominent and keel-shaped, whilst the distance from this latter bone to the spine is much greater than that from side to side. This conformation, especially in quadrupeds in which the clavicles are absent, enables the anterior extremities to approach closely together, and fall perpendicularly downwards beneath the trunk, so as to give it a steady support. The sternum is elongated in these animals, and the ribs pass from the spine to that bone so directly, without any obliquity, that they approach near to the cristæ of the ilia, and thereby increase the extent of firm support necessary to sustain the weight of the viscera. Even with these advantages, the muscles of the abdomen would be inadequate to the support of its contents, were they not assisted by a layer of elastic substance, which is placed over their entire extent, and which of itself marks the destination of such animals for the prone position.

Thorax, expanded laterally; difference in quadrupeds.

Upper limbs have great motion, and little strength.

The scapulæ, placed on the supero-posterior part of the trunk, are borne off by the clavicles; their glenoid cavities are directed forwards and outwards, so that the arms, which are, as it were, appended to them, are fitted to enjoy a

considerable degree of motion in the anterior and posterior directions. But in quadrupeds, the glenoid cavities look downwards, and are approximated closely together, so that the thoracic limbs, which are articulated with them, descend beneath the forepart of the trunk; and as they are thus calculated to support its weight, they possess little lateral motion. The glenoid cavity in man is quite shallow; so that the globular head of the humerus is merely applied to its surface; but the acetabulum is a deep cup-like cavity, indicating a quite different destination of the two joints. The breadth of the articular surfaces of the knee-joint, and the peculiar conformation of the ankle-joint, as contrasted with the elbow and wrist, are abundantly sufficient to show that fixity and strength have been designed in the one limb, mobility in the other. This difference is, if possible, more strongly marked in the conformation of the hand and foot: the latter, as has been already observed, being intended to support the body, is placed horizontally beneath the leg; the former is continuous with the line of direction of the fore-arm, otherwise it could not be guided with sufficient precision to the different objects which it is intended to seize. The tarsal bones are large, firm, and strong; those of the metatarsus are also thick and large, and placed all on a level; that which supports the great toe, being the stoutest of all and almost immovable, ranges with the others. But the metacarpal bones are quite differently disposed; that which supports the thumb admits of considerable motion in every direction, so as to perform a complete circumduction, and is placed so much out of the level of the others that it can be opposed to them, as in grasping different objects. The hand and foot may be considered as divisible each into two parts, differing in their degrees of mobility, viz. the digital phalanges, and the group of bones which sustains them. In the hand the movable phalanges are as long as the carpal and metacarpal bones taken together; but in the foot, they are not a third of the length of the tarsal and metatarsal bones.

Contrast between the hand and foot shows one for tact; the other for support

No part of the osseous system of man affords more striking evidence of his adaptation for the erect posture than the cranium. Resting on the summit of the vertebral column, the line of its base forms a right angle with that of the column itself; and on this it receives a firm support. The condyles, or points of articulation, are situate very near the centre of its base, being, however, a little nearer to the

Upright position of the head on the vertebral column

fits man for erect attitude.

occipital protuberance than to the anterior surface of the jaws; by this arrangement very little, if any effort is required to maintain it *in equilibrio*. In other animals the condyles are placed much farther back; so that, instead of resting on the column, the skull is, as it were, appended to its extremity, and is sustained by an elastic substance, (ligamentum nuchæ,) which is attached on the one hand to the spinous processes of the vertebræ, and on the other to the occipital protuberance.

THE CONNECTIONS OF THE PIECES OF THE SKELETON ONE WITH ANOTHER.

ARTICULATIONS.

Union of skeletal pieces called articulation.

The different pieces of the osseous system are connected together, so as to form a skeleton, and their modes of union as well as their forms and uses are various. When the union is not, as in the cranial bones, immediate, it is effected by means of different substances, such as ligament, cartilage, fibro-cartilage, and fibrous membrane, variously arranged and disposed; so as to permit, in some instances, no perceptible motion, whilst in others a free and extended range is allowed in every direction. Still, all the varieties, however numerous, are usually included under the general term "articulation."

Articulations; three classes.

Classification of Articulations.—The articulations are divided into three classes; viz. the immovable, the movable, and the mixed; the last being intermediate in degree between the others. The first form obtains where flat and broad bones are united to enclose cavities for the lodgement of important organs, as in the cranium and pelvis. In some instances the surfaces are indented and reciprocally impacted one into the other, so that complete solidity is ensured by the structure of the part; and, as this mode of union occurs only amongst flat bones, their deficiency in extent of contact is compensated by the indentations in their margins. There is another set of immovable articulations, in which the surfaces are merely in apposition with one another, yet total immobility is secured by what may be termed a mechanical contrivance. Thus, though the squamous part of the temporal bone merely rests against the inferior border of the parietal, no motion can exist between them, in consequence

of the manner in which the petrous portion of the former bone projects into the base of the skull.

A.—IMMOVABLE ARTICULATIONS.—SYNARTHROSIS.

All the bones of the cranium and face, except the lower jaw, are joined by immovable articulation, or synarthrosis (συν, together, αρθρον, articulation), of which there are several forms. Synarthrosis, various forms of.

1. The first is called *suture* (sutura, a seam). In the true suture the union is effected by prominences and indentations in the contiguous margins of the bones being mutually received into one another, as may be seen in the junction of the two parietal with each other, and with the occipital,[8] and frontal bones; any varieties that occur being referrible to the form of the prominences. Thus, when they are tooth-shaped, the suture is termed *sutura dentata;* if like the teeth of a saw, *sutura serrata;* if the adjacent borders be bevelled off, as where the temporal and parietal bones are applied to one another, it is called a squamous suture (*sutura squamosa*). In some parts it may be observed that the modes of union and adaptation are alternated, in order to increase their power of resistance. Thus, at the superior part of the arch of the skull, the frontal overlays the parietal bones, and rests on them; but inferiorly the reverse takes place, for here the parietal rests upon the frontal. Suture, dentated, serrated, and squamous.

When the surfaces are merely placed in apposition with one another, as in the superior maxillary bones, the union is called *harmonia* (αρω, to adapt). Harmonia.

When a ridge in one bone is received into a groove in another, the articulation is called *schindylesis* (σχινδυλησις, a slit or fissure). The rostrum of the sphenoid, and the descending plate of the ethmoid bone, are joined in this way with the vomer. Schindylesis. When a conical surface is impacted into a cavity, the term *gomphosis* (γομφος, a nail,) is adopted, which may be exemplified by the manner in which the teeth are lodged in the alveoli. Gomphosis.

B.—MIXED ARTICULATIONS.—AMPHI-ARTHROSIS.

In the mixed form of articulation, or *amphi-arthrosis* (αμφι in the sense of αμφω, ambo, and αρθρον,) the bones are connected by an intermediate substance, which allows some degree of motion. The articulations between the bodies of Mixed joints; a connecting substance intervenes

between the bones.

the vertebræ, the union at the pubic symphysis, and that between the first two bones of the sternum, are all constructed on this principle. As the surfaces in these cases are flat and smooth, they possess in themselves no mechanical advantage; so that their union is maintained partly by the cartilages interposed between them, and partly by ligamentous and fibrous structures disposed round the articulations.

C.—MOVABLE ARTICULATIONS.—DIARTHROSIS.

Diarthrosis.

In the movable articulations, or diarthrosis (δια, through, αρθρον, articulation,) as the surfaces are merely in contact with one another, the connection between the parts is maintained by means of ligaments and fibrous membranes; for though cartilages are interposed between their adjacent extremities, they do not form a bond of union between them; on the contrary, they are calculated to facilitate motion, rather than to restrain it. But the muscles which surround the different movable articulations contribute materially to retain the articular surfaces in their natural situations, and to prevent displacement. This is particularly evident in the shoulder-joint, in which the head of the humerus is kept in contact with the glenoid cavity of the scapula, not so much by the fibrous capsule, which is weak and loose, as by the surrounding muscles; for, if these be weakened by paralysis, luxation may be readily produced.

External connecting structures.

Influence of the muscles—

Where movable joints exist.

The joints in the extremities are all referrible to the movable class: so is that of the lower jaw with the skull, and of the latter with the vertebral column.

Shape of the articular ends of bones,

and the names applied in consequence.

In the greater number of instances one of the articular surfaces is convex, the other concave; but each of these forms exhibits some varieties of conformation, which are marked by particular names. Thus, an articulating surface, which is rounded and globular, so as to represent a segment of a sphere, is called a *head;* but if it be elongated, the term *condyle* is used. These are in some cases supported by a contracted or thin portion (*neck*), which connects them with the body of the bone. If two condyles be placed in apposition, so as to leave a fossa between them, and constitute a pulley-like surface, this is termed *trochlea.* When plain even surfaces articulate, it is not necessary to mark them by any particular name; in describing them they are referred to generally as articulating surfaces. Some of the articulating depressions have also received names taken from

certain peculiarities in their conformation. Thus the superior extremity of the ulna, which receives the trochlea of the humerus, is called the sigmoid cavity, from some resemblance to the Greek letter Σ (σιγμα, ειδος, form). Other depressions are denominated from their greater or less degree of depth or shallowness. The deep, cup-shaped cavity which receives the head of the femur is called cotyloid (from κοτυλη, a cup, and ειδος, form); and the shallow oval depression to which the head of the humerus is applied, receives the name of *glenoid* cavity (from γληνη, a shallow cavity, and ειδος, form).

Enarthrosis. The varieties of diarthrosis are :—1. *Enarthrosis* (εν, in, αρθρον, a joint), which in common language is called the "ball-and-socket" joint, such as we see in the hip and shoulder. In this great freedom of motion is provided for.

Arthrodia. 2. *Arthrodia* (αρθρον, a joint, αρω, to adapt); which comprises joints with a limited motion, as in the case of the carpal and tarsal bones, which merely slide for a little way upon each other. The articulations between the tubercles of the ribs and the transverse processes of the vertebræ, and those between the articular processes of the last-named bones, also come under this head.

THE KINDS OF MOVEMENT ADMITTED IN JOINTS.

Kinds of movement. As the extent and form of the articulating surfaces of joints, as well as their ligamentous connections, vary in different instances, so must their degrees of solidity and mobility: and on a review of the whole of the articulations, it may be laid down as a general principle, that the greater their mobility, the less their solidity; or, in other words, that the one is inversely as the other. All the motions, however, which are admissible in joints may be arranged under four heads, viz. motions of gliding, angular movement or opposition, circumduction, and rotation.

Gliding. 1st. The contiguous surfaces of every movable articulation admit a certain degree of *gliding* motion upon one another, so that it may be regarded as common to all; but in some cases it is the only one which takes place, for instance, between the different bones of the carpus and tarsus. We may here observe that some joints admit of all the motions here indicated; some are deprived of rotation, retaining the rest; whilst in others nothing more than a mere gliding can take place between the surfaces; so that a regular gradation is established in their degrees of mobility between

the most movable and those which are least so. The shoulder-joint admits of the greatest extent and variety of movement; the joints between the carpal and tarsal bones are exceedingly limited in those particulars; and, finally, between the latter and those which are altogether immovable, an intermediate grade may be traced, of which the pubic symphysis presents an example.

Angular movement.

2nd. The *angular* movement, or opposition, can take place only between long bones. If two of these, which are articulated together at one extremity, be made to move either towards or from one another, as from extension to flexion, or from adduction to abduction, they include between them an angle varying in magnitude according to the extent of the motion.

Ginglymus.

This, in some cases, as in the elbow and knee, is confined to flexion and extension, which makes them strictly ginglymoid or hinge-joints (γιγγλυμος, a hinge); in others the motion is general, and extends to four opposite directions, including each of the points intermediate between them, as may be observed in the shoulder, in the hip, and the metacarpal joint of the thumb,—all which joints admit of a circumduction.

Circumduction.

3rd. The motion of *circumduction* is performed when the shaft of a bone is made to describe a cone, its summit corresponding with the superior articulation, the base being at the inferior extremity of the bone. While this motion is being executed, the limb passes successively through the states of elevation, abduction, depression, adduction, and of course through all the intermediate points; and if a pencil be held between the fingers, and its point applied to any plain surface, such as a wall, it will trace a circle corresponding with the base of a cone, whose summit is at the shoulder-joint, and whose side coincides with the line described by the out-stretched limb as it traverses the different points just enumerated.

Rotation.

4th. *Rotation* differs altogether from circumduction. In the latter the bone suffers a change of place as it moves from one point to another; in the former, it merely turns on its own axis, and therefore retains the same relative situation with respect to the adjacent parts.

Three varieties.

This movement, however, admits of three varieties; in one, it is performed on a pivot, as in the motion of the atlas on the vertebra dentata; in another there is a sort of compound motion, as for instance, in the rotation of the radius, whose upper end moves in its socket without change

of place, whilst its lower part describes a segment of a circle, and therefore changes place to a certain extent. The femur and humerus also admit of a rotatory motion; in the latter, as the head is closely applied upon the shaft, the axis of motion nearly coincides with that of the bone; but in the former, in consequence of the length of the neck, and of the angle which it forms with the shaft, the rotation is performed round an imaginary axis, which may be conceived to pass from the globular head to the inner condyle.

Various movements of the hip and shoulder.

There are but two articulations, namely, the hip and the shoulder joint, in which all the motions of opposition, circumduction, and rotation can be performed. In these a convex surface is applied to one which is concave, the former being hemispherical, which is essentially necessary to such a freedom of motion. As joints constructed on this principle are more liable to displacement than any others, their security is in a great measure provided for by their being placed at the upper extremity of the limb, by which they are withdrawn from the influence of external forces. This arrangement is made subservient not solely to the security of the joint, but also to a very important purpose in the functions of the limb. For as these free and extended motions are performed in the highest articulation, their effect is communicated to the whole limb, so as to compensate for the more restricted movements in the lower joints.

These joints contrasted.

Though all the motions above mentioned take place in the hip and shoulder joints, each of them, considered singly, is not performed with equal facility in both. Thus, circumduction is executed with greater ease in the shoulder than in the hip. Rotation, on the contrary, is more free and perfect in the latter than in the former. Circumduction can be executed with ease, only when the axis of motion coincides (or very nearly so) with that of the lever to be moved, as is the case in the humerus; but in the femur, the length of the neck of the bone removes the axis of motion considerably from that of the shaft, and thereby impedes circumduction in proportion as it facilitates the rotation of the limb. These differences of structure in the upper joints of the two extremities bear a distinct relation to the conformation of their other articulations, and to the purposes for which they are adapted. For, as the inferior extremity is intended for progression, and to sustain the weight of the body the bones of the leg must be securely fixed, and on this account no pronation or supina-

tion is allowed between the tibia and fibula; but, to co pensate for this deficiency, rotation is permitted in the h But as the superior extremity, on the contrary, is fitted the prehension of objects, and for quick and varied mo ments, free motion is allowed between the bones of the fo arm themselves, and between them and the carpus, in or that the hand and fingers may be more readily directed a applied to such objects as are required to be seized different purposes; and the power of pronation and supi tion, thus conferred, more than compensates for a deficiency in the rotatory motion of the humerus.

Circumstances influencing the degrees of motion in different joints.

It has been already observed, that rotatory motion i bone presupposes the existence of a globular head, placed that its axis shall form an angle with that of the sh Wherever this requisite is wanting, motion is confined opposition and circumduction, as occurs in the articulati of the thumb with the carpus, of the phalanges with metacarpal bones, and of the clavicle with the sternu In each of these joints, the articulating surface of the m movable bone is placed at its end; and as the axis of t bone coincides with that of motion, rotation is prevent but circumduction and opposition are freely perform Should there be limitation in these last movements, it ari generally from the accessory ligaments rather than fr any impediment in the surfaces of the bones; and sho motion in one direction be more free than in another, in the articulations of the digital phalanges with the me carpus, where flexion and extension are more free th abduction and adduction, it proceeds partly from the c dition of the lateral ligaments, and partly from the gr power possessed by the flexor and extensor muscles co pared with those which perform the other movemen But in the knee and elbow though the axis of moti coincides with that of the bones, yet their movement confined to two directions, viz. to flexion and extensio and in these joints, all other motions besides those j mentioned are prevented by the breadth of the articulati surfaces, and by their mode of adaptation; however, wh they are flexed, some degree of lateral motion and circumduction can be performed.

ꞰTICULATIONS OF THE VERTEBRAL COLUMN.

ifferent pieces of the spine are connected together nents, by fibro-cartilage, and in some parts by membranes; the two first serving to retain them situation, the last to facilitate motion between the bones. The bodies are joined by two ligamentous xtending the whole length of the chain, and also by r-vertebral substances. Means by which vertebræ are connected.

ıe *anterior common ligament* (fig. 70,[1]) (ligamentum ıs vertebrarum commune anterius, seu fascia longi- anterior,—Weitbrecht,) is a ɪand of fibres which is placed ront of the bodies of the ver- nd reaches from the atlas to bone of the sacrum, becoming as it descends. It consists of inal fibres which are dense, d well marked. The super- res extend from a given ver- the fourth or fifth below it; ubjacent to these passes from of one to about the third ; whilst the deeper ones pass only from one vertebra ıext it. The band is thicker towards the middle of es of the vertebræ than at their margins, or over the tebral cartilages; by which means the transverse ɔns of the bodies are filled up, and the surface of mn rendered even. It may be observed that the lhere more closely to the margins of the bones than ıiddle of their bodies, and still more closely to the tebral cartilages. Upon the sides of the bodies e some fibres which are thin and scattered, and reach bone to another. Anterior common ligament; its position length of fibres; attachments; lateral fibres.

Fig. 70.*

ıe *posterior common ligament* (fig. 71) (ligamentum e posterius, seu fascia longitudinalis postica,— cht,) is situate within the spinal canal, and at- o the posterior surface of the bodies of the vertebræ; Posterior common ligament; its position

v dorsal vertebræ and parts of some ribs seen from before. 1. ior common ligament. 2. The inter-vertebral substance seen extent. 3. The anterior costo-vertebral or stellate ligament. ıterior or inferior costo-transverse ligament.

it extends from the occiput to the sacrum. It is smooth, shining, and broader at the upper than the lower part of the spine. In the neck it extends all across the bodies, but in the back and the loins it is broader opposite the inter-vertebral cartilages than opposite the bodies of the bones, so that its margins present a series of points or dentations with intervening concave spaces. It adheres firmly to the fibro-cartilages and to the contiguous margins of the bodies of the vertebræ, but it is separated from the middle of the bodies by the transverse parts of the large venous plexus, which is in contact with the bones. Between the ligament and the prolongation of the dura mater which lines the canal, some loose cellular membrane is interposed.

its shape differs along the spine;

where most adherent.

Fig. 71.*

Inter-vertebral substance,

shape and thickness;

connections;

3. The *inter-vertebral substance* (ligamenta inter-vertebralia,—Weitbr.) is a plate or disc of fibro-cartilage (fig. 70,[2]) placed between the bodies of each pair of vertebræ, from the axis to the base of the sacrum; corresponding in shape to the parts of the vertebræ between which it is interposed. These discs are covered anteriorly and posteriorly by the common ligaments which are intimately adherent to them; in the dorsal region they are connected laterally, by short ligaments, to the heads of all the ribs which articulate with two vertebræ.

Fig. 72.†

consists of two parts;

The inter-vertebral substance is composed of an external or laminar part[1] (fig. 72) forming alone the circumference, and of an internal soft or pulpy part[2] which occupies the centre.

external or laminar;

The laminar part forms more than half of the whole mass, and consists of laminæ or

* The arches have been removed from three lumbar vertebræ by sawing through their pedicles. The bodies remaining are seen on their posterior surface, with the posterior common ligament covering them to some extent.

† A lumbar vertebra, with a horizontal section of the inter-vertebral

articulating processes of the first vertebra, which are connected by ligaments and synovial membranes; and partly also by the two following ligaments. two articulations.

The *anterior occipito-atloidean ligament* (fig. 78,[1]) (membrana annuli anterioris vertebræ primæ) extends from the anterior border of the occipital foramen, between the condyles, to the margin of the atlas between the superior articulating processes. This is thin, broad, and membranous; but in the median line, a sort of accessory ligament[2] is placed in front of it, which is thick, round, and composed of vertical fibres, is attached above to the surface of the basilar process, and below to the small tubercle on the front of the atlas. The anterior surface of this ligament is covered by the recti antici muscles, the posterior covers the upper end of the odontoid process and its ligaments. Anterior ligament is thin; thick fibres at middle.

The *posterior occipito-atloidean ligament* (membrana annuli posterioris atlantis) (fig. 79,[1]) also broad and membranous, is attached superiorly to all that part of the margin of the occipital foramen which is behind the condyles, and inferiorly to the adjacent border of the arch of the atlas. It is partly blended with the dura mater. The posterior surface of the ligament is in apposition with the posterior recti and superior oblique muscles, the anterior looks towards the vertebral canal; at each side, near the articular process, the ligament forms part of the canal through which the vertebral artery and sub-occipital nerve pass. Posterior ligament thin; below it, is vertebral artery.

Fig. 79.*

The *articulation of the occipital bone with the axis* is effected through the medium of ligaments, as no part of their surfaces comes into contact; and as the ligaments are placed within the vertebral canal, this must be laid open to exhibit them. Occiput with axis; no articular surfaces; ligaments in vertebral canal.

The *occipito-axoidean ligament* (apparatus ligamentosus) Apparatus ligamentosus.

* The posterior surfaces of the occipital bone, and of three vertebræ, are represented in this figure. 1. The posterior occipito-atloid ligament. 2. The posterior atlo-axoid.

arrangement seen externally, and contains much water structure is fibro-cartilaginous.

Fibres of one plate cross those of another.

The plates of the inter-vertebral tissue being exam singly, it will be f that each consists fo most part of fibres ext ing obliquely between vertebræ, into both which they are fi fixed ; whilst the direc of the fibres varies layer to layer,—in being from right to and in the next the verse (fig. 74,[1 2]). S fibres will be found t nearly horizontal.

Fig. 74.*

Cartilaginous covering to bones.

A thin cartilaginous layer covers those surfaces of vertebræ that give attachment to the discs, but th incomplete towards the circumference.

Proportion of inter-vertebral substance in spine.

The inter-vertebral substance in the column generall Excluding from consideration the first two vertebræ, betw which it does not exist, the inter-vertebral material form length about a fourth of the movable part of the colu But it is not equally distributed among the different regi It varies in thickness from point to point, and the d division of the spine has, comparatively with the lengt much smaller proportion, and has accordingly less provi for pliancy than the cervical or lumbar portions of column.†

Moreover, the discs are not uniform in their thickn

* Two lumbar vertebræ with the inter-vertebral substance are from before. By removing a portion of one layer of the latter, an layer is partly exposed, and the difference in the direction of fibres is made manifest.

† In an elaborate work on the joints and their various movem the brothers W. and E. Weber have given various measurement the individual vertebræ, and the interposed discs, and have grou on them calculations of the degree of flexibility of the column in d ent parts. In order to render their measurements more exac preventing all separation of the parts, they placed a body in plast Paris, (after having removed some of the soft parts, but without in fering with the ligaments,) and when it was immovably fixed by means, a vertical section was made through the middle of the tru dividing it into two equal lateral parts.—See "Mechanik der mens Gehwerkzeuge," S. 90, et seq. Göttingen, 1836.

In the cervical and lumbar regions, which are convex forwards, they are thickest in front; and by comparing the heights of the fore and back parts of the bodies of the vertebræ, and comparing in like manner the heights of the anterior and the posterior margins of the inter-vertebral discs, it has been determined that the convexity of the cervical and lumbar portions of the column is chiefly due to the latter structure,—to it much more than to the bodies of the vertebræ; while the arching of the dorsal region was, on the contrary, found to be owing rather to the shape of the bones. Inter-vertebral substance causes forward curves in the spine.

The *articulating processes* of the vertebræ are connected by irregular fibrous bands (ligamenta processuum obliquorum,—Weitbr.), forming a capsule outside the synovial membrane which belongs to each of the joints. The bands are longer and more loose in the cervical than in the dorsal or lumbar regions. Articulating processes, how connected.

The arches, or plates of the vertebræ, are connected by the *ligamenta subflava* (fig. 75) (ligamenta vertebrarum subflava,—Weitbr.) as their bodies are by the inter-vertebral fibro-cartilages. These ligaments are most distinctly seen when the pedicles and arches are detached from the bodies of the vertebræ, so that they may be viewed from within the spinal canal, as in this drawing (fig. 75); at the posterior aspect of the spine they appear short, and, as it were, overlaid by the arches (fig. 84,[3]). Their attachment extends from the roots of the articular processes at each side backwards to the origin of the spinous process. In the middle line the ligaments are thickest, where their margins are merely in contact. Ligamenta subflava, their position; how brought into view; their extent;

Fig. 75.*

These ligaments consist of yellow elastic fibres, almost perpendicular in their direction, as they pass from one arch to that immediately below it. The superior border of the colour; arrangement of fibres;

* To show the "ligamenta subflava," the pedicles of the vertebræ were sawed through, and the bodies removed. The arches and the processes being left, the ligaments are seen from before, *i. e.* on the surface which looks towards the vertebral canal.

and attachments;

ligament is attached, not to the margin of the arch, but higher up on its anterior surface; whilst the inferior border is inserted into the margin of its corresponding arch, and is prolonged a little on the posterior surface.

where not present.

The ligamenta subflava do not exist between the occiput and the atlas, or between the latter and the axis; common fibrous membrane supplies their place in these two spaces.

The connection of the spinous processes is effected by means of the supra-spinous and inter-spinous ligaments.

Supra-spinous ligament.

1. *The supra-spinous ligament* (ligamenta, queis apices committuntur,—Weitbr.) consists of small compressed bundles of longitudinal fibres, which connect the summits of the spinous processes, and form a continuous chain from the seventh cervical vertebra to the spine of the sacrum. (See fig. 84,[1].) The posterior fibres pass down from a given vertebra to the third or fourth below it; those more deeply seated reach only from one to the next, or the second below it.

Inter-spinous ligaments.

2. The *inter-spinous ligaments* (membrana inter-spinalis—Weitbr.), thin and rather membranous, have an attachment extending from the root to near the summit of each spinous process, and connect the inferior border of one with the superior border of that next below it. They are best seen in the lumbar region, and are least developed in the neck.

Inter-transverse.

The *inter-transverse ligaments* (lig. process. transv.—Weitbr.) are situate between the transverse processes, but their condition varies in different regions.* In the loins they are membranous; in the back, rounded bundles; and in the neck they may be wanting, or may exist only at the tip of the united transverse processes.

ARTICULATIONS OF THE TWO UPPER VERTEBRÆ ONE WITH ANOTHER.

Atlas with axis; no inter-vertebral substance;

peculiar connection with

The articulation of the axis with the atlas is effected by means of their articulating processes; also (in the place of inter-vertebral substance, which would be altogether incompatible with the requisite movements) by the odontoid process of the former, which is connected in a particular

* In the dorsal region they are united so intimately with the sacro-lumbalis muscle, that their fibres are quite indistinct; indeed, they appear to be rather appendages to the muscles than ligaments to connect the bones; and they are so considered by Weitbrecht, Meckel, and Sœmmerring.

manner with the arch of the latter, and constitutes the pivot on which the head turns in its rotatory motions. There are three ligaments and four synovial membranes in this articulation. odontoid process.

The *transverse ligament* (fig. 76,[2] and 77,[2]) (ligamentum transversale: pars principalis,—Weitbr.) is placed transversely behind the odontoid process of the axis, and forms with the anterior arch of the atlas a ring,[1] in which that process is lodged: it divides thus the great foramen of the first vertebra into two parts of unequal size, of which the larger[3] is appropriated to the spinal cord, and the smaller[1] is occupied in the manner already stated. Transverse ligament; divides ring of atlas into two parts;

Fig. 76.*

The ligament is a strong, thick fasciculus of fibres, compressed from before backwards, arched in its direction as it crosses the odontoid process, and attached on each side to a tubercle below the inner border of the superior articulating process of the atlas. The ligament is broader and thicker at the middle than at the extremities; and from the middle of its posterior surface a short thin bundle of fibres passes down to be attached to the body of the axis, whilst another passes up to the basilar process. *These appendages* (lig. transv. appendices,—Weitbr.) form a cross with the transverse ligament, and serve to bind the occiput to the first two vertebræ; from this is derived the term *cruciform*, which is sometimes applied to the transverse ligament and its appendages together (fig. 77). crosses odontoid process. With its appendages it is cruciform.

Fig. 77.†

* A view of the atlas from above, showing the transverse ligament, with fragments of its appendages. 1. The space for the odontoid process. 2. The transverse ligament. 3. Space for the spinal cord. 4. Articular processes;—on one of these a remnant of the capsular membrane is seen.

† A small portion of the skull, and the first two vertebræ are shown in this figure. They are viewed from behind. The back parts of the

[redacted]

the rough unarticulated part of the tubercle of the rib. Those of the superior ribs ascend, those of the inferior descend somewhat.

Fig. 84.*

inter-osseous or middle;

2. The *middle* or *inter-osseous costo-transverse ligament* (fig. 85,[6]) consists of a series of very short parallel fibres, which unite the neck of the rib to the anterior surface of the contiguous transverse process. These fibres are seen by removing horizontally a portion of the rib and transverse process, and forcibly drawing the one from the other.

and anterior or long,

3. The *anterior* or *long costo-transverse ligament* (figs.

Fig. 85.†

70, 84,[4]) (lig. transversarium internum, seu cervicis

* A few dorsal vertebræ, and ribs connected with them, are seen from behind. 1, 2, are on the laminæ of vertebræ, close to the inter-spinous ligaments. 3, is one of several ligamenta subflava represented in the figure. They are but slightly seen, being for the most part covered by the plates of the vertebræ: see figure 75. 4. The anterior costo-transverse ligament. 5. The posterior costo-transverse ligament.

† A horizontal section of a vertebra and portions of two ribs, to show the inter-osseous ligament connecting the neck of the rib to the transverse process of the vertebra on each side. 1. The rib. 2. Transverse process. 3. Lig. capit. costæ. 5. Posterior costo-transverse ligament. 6. Inter-osseous or middle costo-transverse ligament.

costæ internum,—Weitbr.) is usually divided into two fasciculi of fibres, both nearly in apposition, and on the same plane. They pass from the neck of the rib obliquely upwards and outwards to the lower margin of the transverse process next above it. By the outer margin the ligament is continuous with a thin fibrous membrane occupying the interval between the ribs. This ligament does not exist in the articulation of the first rib. is continuous with fascia; where absent.

The articulation between the tubercle of the rib and the transverse process is provided with a *synovial sac*, except in the case of the two lowest ribs. Synovial sac.

c. The *costo-sternal articulations*, situate between the anterior angular extremities of the cartilages of the ribs and the corresponding fossæ in the margins of the sternum, are covered and supported by, *a*, an anterior set of ligamentous fibres (fig. 86,[6]), thin, scattered, and radiated (ligamenta radiatim disiecta,—Weitbr.), passing from the extremity of the cartilage to the anterior surface of the sternum, where they interlace with those of the opposite side, and are blended with the aponeurosis of the pectoralis major muscle; *b*, a posterior set of fibres similarly disposed, but not so thick or numerous, connecting the thoracic surfaces of the same parts; *c*, some ligamentous fibres placed above and others below the joint; *d*, a *synovial membrane*, interposed between the end of the cartilage of each true rib and the sternum: this last can be demonstrated by slicing off a little of the anterior surface of the sternum and cartilage. Cartilage of rib with sternum. Anterior ligament radiated; posterior ligament; superior and inferior fibres. Synovial sac.

Fig. 86.*

A thin fasciculus of fibres connects the cartilage of the seventh rib (and it may be, likewise, of the sixth) with the xiphoid cartilage, and is thence called the *costo-xiphoid ligament.* Costo-xiphoid.

Articulation of the cartilages one with another.—The Cartilages together.

* A portion of the sternum with the inner ends of the clavicles, and of some of the ribs, is here represented.

1. The anterior sterno-clavicular ligament. 2. Inter-clavicular. 3. Costo-clavicular or rhomboid. 4. Inter-articular fibro-cartilage. 6. Costo-sternal ligament.

contiguous edges of the cartilages of the ribs, from the sixth to the ninth, have articular surfaces, which are lined by synovial membranes, and held in connection by ligamentous fibres. Some of the articular surfaces are from time to time found to be wanting.

Rib with its cartilage

Connection of the ribs with their cartilages.—The external extremities of the cartilages are received into rounded depressions on the ends of the ribs, and the union receives support from the periosteum.

Articulations of sternum by cartilage.

Ligaments of the sternum (membrana sterni,—Weitbr.)—The two pieces of the sternum are united by a layer of cartilage, placed between their contiguous borders; and, on the anterior and posterior surfaces ligamentous fibres may be observed running longitudinally, which serve to strengthen their connection: these are sometimes called the *anterior* and *posterior sternal* ligaments. The longitudinal fibres are mixed with those radiating from the costal cartilages, especially in front of the sternum, where likewise they blend with the aponeuroses of the pectoral muscles. The anterior portion has thus most accessory fibres, and is rough and irregular; the posterior one is smooth and pearly in its aspect.

and bands before and behind.

ARTICULATIONS OF THE UPPER EXTREMITY.

The scapular arch and the upper limb have but one point of attachment to the trunk, namely, that at the sterno-clavicular articulation,—the scapula being connected with the trunk only by muscles.

Arrangement of the articulations.

The several articulations of these parts may be arranged under the following heads, taking them in their anatomical order, from above downwards: 1, the articulations of the clavicle at one end with the sternum, and at the other end with the scapula; 2, those of the scapula and the humerus; 3, of the elbow; 4, of the radius and ulna; 5, of the wrist; 6, of the metacarpus; 7, of the fingers.

ARTICULATION OF THE CLAVICLE WITH THE TRUNK AND THE SCAPULA.

Clavicular articulations.

The clavicle articulates by its inner end with the first bone of the sternum, and is there connected by ligaments to its fellow of the opposite side and to the first rib. The outer end of the bone is joined with the scapula.

Sterno-clavicular articulation.—The articular surface of the inner end of the clavicle is considerably larger than that of the sternum, and both are somewhat concave and convex. The other structures of which the joint consists are, an anterior and a posterior ligament, an inter-articular fibro-cartilage, and two synovial membranes. Clavicle with sternum.

The *anterior sterno-clavicular ligament* (fig. 86,[1]) passes from the inner extremity of the clavicle, downwards and inwards, upon the surface of the sternum. It is broad, and consists of parallel fibres; it corresponds, internally, with the synovial membranes of the articulation, and with the inter-articular fibro-cartilage, to which it is adherent; externally, with the sternal origin of the sterno-mastoid muscle. Sterno-clavicular ligaments, anterior,

The *posterior sterno-clavicular ligament*, of similar conformation with the last, but not so broad or strongly marked, is placed between the same bones, lying at the thoracic aspect of the joint. Its posterior surface is in relation with the sterno-hyoideus and sterno-thyroideus muscles. posterior.

The *inter-articular fibro-cartilage*,[4] nearly circular in its form, and thicker at the border than at the centre, is interposed between the articulating surfaces of the sternum and clavicle. Towards its upper part it is attached to the surface of the clavicle, and at the opposite point to the cartilage of the first rib. In the latter situation it is thin and somewhat prolonged, so that the inferior border of the clavicle rests upon it. Inter-articular fibro-cartilage, fixed to bones.

Synovial membranes.—In this articulation, as in that of the lower jaw, there are two synovial membranes; of which one belongs to the sternal end of the clavicle and the adjacent surface of the fibro-cartilage; the other is disposed between the cartilage and the articulating surface of the sternum. Two synovial sacs.

The *inter-clavicular ligament*[2] is a dense fasciculus of fibres, between the contiguous extremities of the clavicles. Its fibres do not pass directly across from the one bone to the other; they dip down, and are attached to the upper margin of the sternum, so that the ligament is rendered concave from side to side. Inter-clavicular ligament.

The *costo-clavicular ligament*[3] (ligamentum rhomboides,—Weitbr.) does not properly form part of the articulation; yet it contributes materially to retain the clavicle in its situation. It is attached inferiorly to the cartilage of the first rib near its sternal end, and passes obliquely backwards Clavicle with first rib; rhomboid ligament.

and upwards, to be fixed to a tubercle at the under surface of the clavicle near the sternal end.

Clavicle with scapula.

Connection of the clavicle with the scapula.—At its outer end the clavicle articulates directly with the acromion, and is connected by ligamentous fibres with the coracoid process.

Acromio-clavicular ligaments; superior; inferior. Synovial sac.

The *acromio-clavicular articulation* is effected between the acromion process of the scapula and the external end of the clavicle, each of which presents a small oval articular surface. These surfaces are connected, 1st, by a *superior ligament* (fig. 87,[1]), which is a thick, broad band of fibres, passing from the superior surface of the acromion to the adjacent extremity of the clavicle; 2ndly, by an *inferior ligament* similar to the preceding, but less thick, and placed at the under surfaces of the same bones; 3rdly, by a synovial membrane for the articular surfaces of the bones.

Fig. 87.*

Fibro-cartilage usually wanting; may be imperfect; rarely complete.

An *inter-articular fibro-cartilage* is sometimes present, but it is more frequently wanting.† It has, in some instances, been found to extend through part of the joint, so as only partly to separate the bones; ‡ but in other instances the fibro-cartilage is as distinct in this joint as it is in the temporo-maxillary articulation; the last condition, however, is of rare occurrence.

One synovial sac usually.

A *synovial membrane* lines the ligaments, and covers the articular surfaces of the bones in the usual manner. When there is an inter-articular cartilage which separates the bones completely, there are two narrow synovial sacs, dis-

* The scapula of the right side (its inner or concave surface) is here shown in connection with a considerable part of the clavicle and the upper end of the humerus. The tendon of the biceps muscle hangs over this; but the capsule must have been cut through, to expose it so far up.

1. Acromio-clavicular ligament. 2. Coraco-clavicular (conoid and trapezoid). 3. Lig. proprium posterius (scapulæ). 4. Lig. propr. anter. 5. Capsular ligament. 6. Coraco-humeral.

† "Mihi vix vna alteraue vice inuenire contigit, etiamsi saepius studiose quaesiuerim."—Weitbrecht, "Syndesmologia," p. 17.

‡ Monro, "The Anatomy of the Human Bones," &c. fourth ed. p. 173; and Weitbrecht, Op. cit. p. 17, and tab. i. fig. 4.

[redacted]

posed in the same way as those in the sterno-clavicular articulation.

Coraco-clavicular ligament; The *coraco-clavicular ligament* (fig. 87,[2]), which connects the clavicle with the coracoid process of the scapula, presents two parts, each known by a particular name. There is, however, little division between them; the chief distinction being that each has a different form and direction.

conoid part; The *conoid ligament*, which is the posterior or internal fasciculus, broad above, narrow below, is attached inferiorly to the inner part of the root of the coracoid process; superiorly to a tubercle at the inferior surface of the clavicle, towards the outer end; its fibres are directed backwards and upwards. **trapezoid part.** The *trapezoid ligament*—the anterior or external fasciculus—passes upwards from the inner border of the coracoid process, to an oblique line extending outwards from the tubercle into which the conoid ligament is inserted; with the latter it unites behind at an angle, one of its aspects being directed forwards and upwards, the other downwards and backwards.

Proper ligaments of scapula; posterior small; converts notch into foramen; *Ligaments of the scapula.*—There are two special ligaments for the scapula: 1. The *coracoid ligament*[3] (ligamentum proprium posterius) is a thin flat band of fibres, attached by its extremities to the opposite margins of the notch at the root of the coracoid process, which it thus converts into a foramen for the transmission of the supra-scapular nerve, the artery most commonly passing external to it. **anterior (coraco-acromial) is triangular.** 2. The *coraco-acromial ligament*[4] (ligamentum proprium anterius) is a broad, firm, triangular fasciculus, attached by its broader extremity to the outer edge of the coracoid process, and by the narrower to the tip of the acromion, between which it is stretched almost horizontally. Its inferior surface looks downwards upon the shoulder-joint, the superior is covered by the deltoid muscle.

THE SHOULDER-JOINT.

Bones in the joint. The globular head of the humerus and the glenoid cavity of the scapula are the osseous parts which compose this articulation (*scapulo-humeral*). As the head of the humerus is large and prominent, whilst the cavity is merely a superficial depression, it is evident that it must be retained in its situation not by any mechanical contrivance, but by the muscles which are attached to the two tuberosities of the humerus.

Capsular ligament, how attached;

The *capsular ligament* (fig. 87,[5]) is fixed superiorly ro
the margin of the glenoid cavity, and inferiorly round
neck of the humerus, or rather a little beyond this,
more so on the lower than the upper part of the bone.
much stronger in the latter than in the former situation ;

its laxity:

its laxity is such, that, if the muscular connections of
humerus be detached, this bone drops away from the gle

where strongest.

cavity. The superior and outer part of this membran
covered and strengthened by a bundle of fibres,[6] pas
outwards and forwards from the coracoid process to the g
tuberosity of the humerus (*coraco-humeral ligament*). Be
this, it receives additions from the thick tendons of
supra and infra spinatus, and the teres minor muscles, w

Connection with muscles.

are intimately connected with it, as they pass over i
reach the great tuberosities of the humerus. By mean
these accessory structures the superior part of the capsu
thick and firm, while the inferior is comparatively thin
weak. At the inner side the ligamentous fibres of the
sule are wanting for a small space ; and here the upper

Foramen for subscapular muscle;

of the tendon of the subscapularis muscle comes into con
with the synovial membrane, which projects through
opening (foramen ovale). The fibrous capsule is lined by
synovial membrane. The external surface is covered by
deltoid, in addition to the muscles already mentioned ;
feriorly, it is in relation with the long head of the triceps

foramen for tendon of biceps.

the circumflex vessels. The insertion of its inferior bord
interrupted to give passage to the long tendon of the bi
muscle.

Coraco-humeral ligament.

The *coraco-humeral*, or accessory ligament,[6] above noti
extends obliquely over the upper and outer part of
articulation ; it is attached to the root of the coracoid
cess, and thence descends, intimately connected with
capsule, to the greater tuberosity of the humerus.

Glenoid ligament continuous with tendon of biceps.

The *glenoid ligament* is a firm fibrous band, about
lines deep, which is fixed to the edge of the glenoid fo
and, by elevating the border of the cavity, renders
little deeper. Some of its fibres are derived from
tendon of the long head of the biceps muscle, where th
fixed into the upper part of the glenoid fossa.

Synovial membrane,

The *synovial membrane* is reflected from the circumfere
of the glenoid cavity, and so reaches the inner surface
the fibrous capsule ; on this it is prolonged as far as
neck of the humerus, where it separates from the capsu

its reflection,

and is lost upon the articular surface of the head of t

bone. Viewed in this way, it appears a shut sac; and such it would be but for the peculiar relation of the long tendon of the biceps muscle to the shoulder-joint. The tendon lies in the centre of the joint; but it is enclosed in a tubular sheath, formed by an offset or process of the synovial membrane, which is reflected upon it where it is about to pass through the fibrous capsule, and is thence continued up to the summit of the glenoid cavity. By this provision the integrity of the membrane is preserved.

has a tube for tendon of biceps.

On the outer surface of the muscles covering the top of the joint is a considerable *bursa mucosa*, by means of which the contiguous surfaces of the coracoid and acromion processes, and of the coraco-acromial ligament and deltoid muscle are lubricated, so as to facilitate the movements of the subjacent head of the humerus.

Synovial bursa outside joint.

THE ELBOW-JOINT.

The lower extremity of the humerus is connected with the ulna and radius at the elbow, and forms with them a hinge-joint. The sigmoid cavity of the ulna articulates with the trochlea of the humerus, so as to admit of flexion and extension only; while the cup-shaped depression on the head of the radius is fitted to turn freely on the rounded tubercle opposite it. The bones are connected by four ligaments with a synovial membrane.

Articular surfaces; kind of movement.

The *internal lateral ligament* (fig. 88,[1]), composed of diverging and radiated fibres, presents two parts, each with a different aspect, one looking obliquely forwards, the other backwards. The anterior part is attached above, where it is narrow and pointed, to the front of the internal condyle of the humerus; its fibres, as they descend, diverge from one another, and are inserted into the coronoid process, along the inner margin of the sigmoid cavity. The posterior part, of the same form (triangular), passes from the under and back part of the same process of bone downwards to the inner border of the olecranon; and some fibres are connected with a small transverse band over the notch, between the olecranon and the coronoid process, which transmits vessels.

Internal lateral ligament, is triangular; its attachments.

Aperture for vessels.

The *external lateral ligament* (fig. 89,[2]), shorter and much narrower than the internal, is attached superiorly to the external condyle of the humerus, and inferiorly becomes blended with the annular ligament of the radius; some of its hinder fibres are prolonged to the external margin of the

External lateral ligament attached to orbicular ligament, and the ulna.

ulna. It is intimately connected with the tendinous attach
ment of the extensor muscles; on which account, whe
dissected, it presents a jagged irregular appearance.

Fig. 88.*

Fig. 89.*

Anterior ligament. The *anterior ligament* (fig. 88,[3]) is a broad thin membran
placed in front of the joint, extending from the front of th

* Figures 88 and 89 are front and back views of the bones an
ligaments of the left fore-arm and hand. 1. The internal lateral lig

humerus downwards to the anterior part of the coronoid process, and to the annular ligament of the radius. Some of its fibres are directed obliquely downwards and outwards, others are vertical. It is continuous at each side with the two preceding ligaments.

Posterior ligament indistinct and loose. The *posterior ligament*, (fig. 89,[4]) loose and weak, consists of fibres proceeding in different directions; thus some pass transversely between the opposite margins of the fossa which receives the top of the olecranon; whilst others, subjacent to these, but not very well marked, pass vertically from the upper concave margin of that fossa to the extremity of the olecranon.

The ligaments are all continuous one with another. Though these structures are described as separate ligaments, it will be found, on examination, that they form a continuous membrane placed round the joint, as fibrous capsules usually are; but in consequence of the irregularity of the surfaces to which they are attached, they have the appearance of distinct ligaments passing from one point of bone to another.

Synovial membrane, The *synovial membrane* of the elbow-joint is prolonged from the articular extremity of the humerus, a little on the anterior surface of that bone, as far as the attachment of the anterior ligament, where it is reflected, and applied to the internal surface of that ligament, lining it as far as the lower insertion. At that point the synovial membrane leaves the fibrous one, and, guided by the radius and ulna, comes into apposition with the posterior ligament, by which it is conveyed to the extremity of the humerus. **extends between radius and ulna, and beneath orbicular ligament.** Besides these reflections, the membrane forms a large pouch, which is prolonged into the joint between the small sigmoid cavity of the ulna and the head of the radius, as well as between the annular ligament and the contiguous surface of the head and neck of the radius.

Osseous surfaces. When the joint has been laid open, and fully extended, it will appear that the head of the radius is not in contact with the rounded articulating process of the humerus. On which

ment. 2. The external lateral. 3. The anterior. 4. points to the posterior. 5. Orbicular ligament of the radius. 6. Inter-osseous membrane. 7. Round ligament. 8. Internal lateral ligament of the wrist. 9. External of the same. 10. Anterior. 11. Posterior. 12. Palmar, and 13, dorsal carpo-metacarpal ligaments. 14. Ligaments connecting metacarpal bones. 15. Transverse metacarpal ligament. 16. Carpo-metacarpal ligament of thumb (capsular). 17. Lateral ligaments connecting the phalangal to the metacarpal bones. 18. Lateral ligaments of phalanges.

account, in the extended state of the limb, the rotatory motions of the radius are performed with much less ease than in that of flexion, from its wanting support at the upper end. The part of the humerus here referred to is moreover covered with cartilage only on its anterior aspect, indicating that the radius moves on it only when the limb is in the flexed position.

THE UPPER RADIO-ULNAR ARTICULATION.

Articular surfaces

The head of the radius articulates with the small sigmoid cavity of the ulna, on which it rolls when it is made to turn on its axis. These surfaces are covered with cartilage, and provided with the synovial membrane of the elbow-joint. The radius is connected to the ulna by an annular ligament.

Synovial sac from elbow-joint.

Fig. 90.*

Orbicular ligament attached to ulna,

The *annular* or *orbicular ligament* (ligamentum orbiculare radii,—Weitbr.) (figs. 88, 89,[5]) is a strong band of circular fibres, which, by being attached to the borders of the small sigmoid cavity, forms a ring (fig. 90,[5]) encircling the head of the radius, and binding it firmly in its situation. The external surface is connected with the external lateral ligament of the elbow, whose fibres are inserted into it; the internal is smooth, and is lined by the synovial membrane of the elbow-joint.

connected with external lateral ligaments.

THE MIDDLE RADIO-ULNAR ARTICULATION.

Ligaments are:—

The interval between the radius and ulna in the fore-arm is occupied by an inter-osseous ligament and a round ligament, which serve to connect them together, and form what is called the middle radio-ulnar articulation.

Inter-osseous membrane;

The *inter-osseous membrane* (figs. 88, 89,[6]) (membrana interossea) is a thin, flat, fibrous membrane, the direction of

* The upper end of the ulna, with the orbicular ligament for the head of the radius. 1. Olecranon. 2. Coronoid process. 5. Orbicular ligament.

whose fibres is for the most part obliquely downwards and inwards, from the inner sharp border of the radius to the contiguous one of the ulna. It does not reach the whole length of the bones, as it commences about an inch below the tubercle of the radius. The surfaces of this membrane are intimately connected with the deep-seated muscles of the fore-arm, serving to increase their points of origin as well as to connect the bones. Above the lower margin there is an opening for the transmission of the anterior inter-osseous vessels to the back of the fore-arm ; and the posterior inter-osseous vessels pass backwards in the space above the membrane (hiatus interosseus). Some small bundles of fibres, having the same direction as the round ligament described below, are often to be found at intervals on the posterior surface of the inter-osseous membrane.*

direction of fibres; does not reach upper end of bones.

Foramen for artery.

Hiatus interosseus.

The *round ligament* (ligamentum teres, v. chorda transversalis,—Weitbr.) (fig. 88,[7]) in some measure supplies the deficiency left by the inter-osseous ligament at the upper part of the fore-arm. It is a thin, narrow fasciculus of fibres extending obliquely downwards and outwards from the coronoid process, to be attached to the radius about half an inch below the tubercle. The direction of the fibres is therefore altogether different from that of the fibres of the interosseous ligament.

Round ligament, higher than inter-osseous membrane;

direction different.

THE LOWER RADIO-ULNAR ARTICULATION.

At the lower or carpal extremities of the radius and ulna, the former rotates on the latter as its point of support, the articulating surface of the radius being concave, that of the ulna convex. The bones are connected anteriorly and posteriorly by some fibres passing between their extremities, so thin and scattered as scarcely to admit or require description ; but internally they are joined by a fibro-cartilage with a synovial membrane.

Bones in the joint,

and ligaments.

The *fibro-cartilage* (cartilago intermedia triangularis,—Weitbr.), *triangular* in form, and thick, is placed transversely between the bones (fig. 91,[6]). It is attached by its base to a ridge separating the carpal from the ulnar articulating surface of the radius ; and by its apex to a depression at the root of the styloid process of the ulna, and to the side of that process. The upper surface of the fibro-

Triangular fibro-cartilage fixed to bones at base and apex;

* Weitbrecht, Op. citat., p. 34, and fig. 11.

cartilage looks towards the head of the ulna, the lower to the cuneiform bone; both are smooth, and lined by synovial membrane;—the inferior one by the large membrane of the wrist-joint, the superior by a small sac belonging to the radio-ulnar articulation. Its two borders are connected with the ligaments of the wrist. There is occasionally a perforation in the middle of the fibro-cartilage. As the radius rolls on the ulna, this cartilage is carried with it, and forms its chief bond of union with the latter bone.

is between two synovial sacs;

these may join.

Fig. 91.*

Membrana sacciformis;

The *synovial membrane* is frequently called *membrana sacciformis*, though there is nothing in its conformation, except, perhaps, its looseness, which distinguishes it from other synovial sacs. It may be considered as presenting two parts, one projecting perpendicularly upwards into the articulation of the radius and ulna; the other placed horizontally between the head of the ulna and the corresponding surface of the fibro-cartilage; both, however, are parts of a continuous membrane. This "sacciform" synovial membrane is continuous with that of the wrist-joint, when the triangular fibro-cartilage, being perforated, is insufficient to form a complete barrier between the two membranes.

between radius and ulna, and between latter and fibro-cartilage.

THE WRIST-JOINT.

Articular surfaces.

This articulation (*radio-carpal*) is formed above by the radius and the triangular fibro-cartilage, and below by the first three bones of the carpus. The articular parts of the first two, when viewed in the fresh state, present an oval and slightly concave surface, whose greatest breadth is from side to side. The surface of the radius is divided into

* The lower ends of the radius, and ulna, with the triangular fibro-cartilage connecting them. 1. Ulna; 2, its styloid process. 3. Radius. 4, its articular surface for the scaphoid bone, and 5, that for the semilunar. 6. The triangular fibro-cartilage; its lower surface. A piece of whalebone (*) has been passed between its upper surface and the head of the ulna.

two parts by a line extending from before backwards; so that these, together with the cartilage, present three articular surfaces, one for each carpal bone. The scaphoid, semi-lunar, and cuneiform bones are articulated together, so as to form a rounded convex surface, which is received into the concavity above described. Four ligaments and a synovial membrane retain these parts in their situation, as follow:—

Internal lateral ligament.

The *internal lateral ligament* (figs. 88, 89,[8]) passes directly downwards from the extremity of the styloid process of the ulna, to be attached to the cuneiform bone; it also sends some fibres to the anterior annular ligament and the pisiform bone. Its form is that of a rounded cord; its inner surface is in contact with the synovial membrane of the radio-carpal articulation.

External lateral ligament.

The *external lateral ligament*[9] extends from the styloid process of the radius to a rough surface on the outer side of the scaphoid bone, some of its fibres being prolonged to the trapezium, and also to the annular ligament of the wrist.

Anterior ligament.

The *anterior ligament*,[10] (*radio-carpal*,) broad and membranous, is attached to the rough border of the carpal extremity of the radius, and to the base of its styloid process; from which its fibres pass down to be inserted into the anterior surface of the scaphoid, semi-lunar, and cuneiform bones. It is pierced by several foramina for the transmission of vessels: one of its surfaces is lined by the synovial membrane of the joint, the other is in contact with the tendons of the flexor muscles.

Posterior ligament.

The *posterior ligament*[11] extends obliquely downwards and inwards, from the extremity of the radius, to the posterior surface of the first row of the carpal bones; its fibres appear to be prolonged for some way on those bones. One surface is in contact with the synovial membrane, the other with the extensor tendons. Both the anterior and posterior ligaments are connected to the sides of the triangular fibro-cartilage which binds the radius to the ulna. The whole of the preceding ligaments are continued into each other around the wrist-joint without interruption.

All are continuous one with another.

Synovial sac.

The *synovial membrane* is reflected from the radius and the triangular fibro-cartilage, on the surrounding ligaments, to the carpal bones.

ARTICULATIONS OF THE CARPAL BONES ONE WITH ANOTHER.

Bones joined in rows.

The bones of the carpus constitute two sets, those of each set being united by special ligaments, so as to form a row; and the two rows, connected by fibrous bands together with a synovial membrane, form between them a joint.

Bones of first row

The uniting structures proper to the first row are inter-osseous bands, and ligaments placed on the dorsal and palmar surfaces.

connected by inter-osseous,

The *inter-osseous* ligaments are placed on the sides of the semi-lunar bone, one connecting it with the scaphoid, and the other with the cuneiform bone. Their free surfaces are smooth, and covered by synovial membrane.

palmar,

The *palmar ligaments* are two, one extending from the scaphoid bone to the semi-lunar, the other from the semi-lunar to the cuneiform, their direction being transverse. The

and dorsal ligaments.

dorsal ligaments are also two, disposed similarly, and connecting the same bones on their posterior surfaces.

Articulation of pisiform bone; capsule and sac.

The pisiform bone stands out of the range, and rests on the palmar surface of the cuneiform, with which it is articulated by an irregular *fibrous capsule* and a *synovial membrane.* There are likewise two strong ligaments, by one of which the bone is connected to the unciform, and by the other to the fifth metacarpal bone.

Bones of second row, means of connection nearly same.

The carpal bones of the second range are also connected by similar means. There are three *dorsal* and three *palmar ligaments*, one of each kind passing transversely between each two contiguous bones. There are *inter-osseous* bands between the adjacent osseous surfaces; and that between the trapezium and the os trapezoides is the least strong.

First row to second row,

The ligaments which connect the upper to the lower row of bones are situate at the palmar, dorsal, and lateral aspects.

by lateral ligaments,

The *lateral ligaments* are placed one at the radial, the other at the ulnar border of the carpus; the former connects the scaphoid bone with the trapezium, the latter the cuneiform with the unciform.

palmar and dorsal.

The *palmar* or anterior ligament consists of fibres, which pass obliquely from the bones of the first to those of the second range. The *dorsal*, or posterior, is similar in structure and arrangement.

Form of the joint.

Form of the joint.—It may be observed, that the first range of carpal bones forms a concavity; the second, par-

ılarly the os magnum and unciform, a convexity which is eived within it ; by these means a ball-and-socket joint is med, which is lubricated by a synovial membrane.

Synovial membrane.—This membrane enters into the iculations of all the carpal bones with each other, except ıt of the pisiform, and serves also for the joint between ; two rows ; it sends two processes between the three bones the first row, and three between the four bones of the second, as to facilitate their respective motions. Moreover it is ıtinued downwards to the joints formed between the pal and the four metacarpal bones of the ulnar side of ; hand ; and in some cases there is a continuity with the ıovial membrane belonging to the wrist-joint.

Synovial sac ; lines carpal joints, and carpo-metacarpal articulations, and sometimes reaches wrist.

CARPO-METACARPAL ARTICULATIONS.

The last four metacarpal bones are connected with those of ; carpus by means of two sets of fibrous bands, one on the lmar (fig. 88,[12]), the other on the dorsal surface (fig. 89,[13]), ; latter being the better marked.

Kind of ligaments.

Dorsal ligaments.—All but the fifth metacarpal bone ;eive two bands. Thus to the second, or that of the fore-ger, a thin fasciculus of fibres passes from the trapezium, other from the trapezoid bone ; the third receives one from ; last bone, and from the os magnum ; the fourth from ; os magnum and also from the unciform ; but the fifth is ınected to the unciform only. On the *palmar* surface a ıilar mode of connection exists, but the fibres are not so ll defined ; there is a single band to each bone, except ıt of the little finger.

Dorsal, and palmar ligaments.

Inter-osseous ligament.—There is likewise a separate ;er-osseous band in one part of the carpo-metacarpal ;iculation,—which connects the lower and contiguous rners of the os magnum and unciform to the ulnar side of ; base of the third metacarpal bone. This ligament is ;played by removing the dorsal ligaments, and with them portion or layer of the osseous structure. The *synovial* ;*mbrane* for the four ulnar carpo-metacarpal articulations continued from that which lines the articulations of the rpal bones one with another : occasionally the last two meta-rpals will have a separate synovial sac in their joint with e unciform bone.

Inter-osseous ligament.

Synovial sac, one or two.

The *metacarpal bone of the thumb* is articulated on quite lifferent plan from the others ; and, as it admits of all

The thumb ; its free movement.

the motions except rotation, it is connected to the trapezium by a capsular ligament (membranula capsularis,—Weitbr.),[illegible] which passes from the rough border bounding its articular surface to the trapezium. This joint possesses a separate *synovial membrane.*

Capsular membrane, and separate synovial membrane.

CONNECTION OF THE METACARPAL BONES ONE WITH ANOTHER.

Bones joined by dorsal, palmar, and inter-osseous ligaments.

The *carpal extremities*, or *bases*, of the last four metacarpal bones are bound together by three transverse fibrous bands,[illegible] on the palmar, and the same on the dorsal surface ; these are slight, and often ill-defined, and pass from one bone to another. The bones are likewise bound together by numerous *inter-osseous* ligamentous fibres between their lateral surfaces : a portion of these surfaces, viz. where they are in contact, is covered with cartilage, and is supplied with synovial membrane continued down between the metacarpal bones from the carpo-metacarpal articulation.

Synovial membrane is continued from above.

Heads of metacarpal bones.

The *digital extremities* (*heads*) of the metacarpal bones are connected at their palmar aspect by thin ligamentous fibres passing across them from one to another. The whole is called the *transverse ligament* (membrana ligamentosa,—Weitbr.). Its place is indicated, fig. 88,[18]; but it is better shown, though not numbered, in fig. 89, at the metacarpo-phalangeal joints.

Transverse ligament.

ARTICULATIONS OF THE METACARPAL BONES WITH THE PHALANGES, AND OF THE LATTER ONE WITH ANOTHER.

Articular surfaces, and ligaments.

The rounded head of each of the last four metacarpal bones, being received into the slight concavity in the extremity of the first phalanx, is maintained in its position by two lateral ligaments, an anterior ligament, and a synovial membrane.

Lateral ligaments.

The *lateral ligaments* consist of dense and thick fasciculi of fibres (fig. 88,[17]), placed one at each side of the joint ; they are attached each by one extremity to the side of the metacarpal bone, and by the other to the anterior ligament and the contiguous extremity of the phalanx. The direction of the fibres is downwards and forwards.

Palmar is joined to lateral ligaments.

The *anterior* or *palmar* ligament occupies the interval between the foregoing on the palmar aspect of each joint ; it is a very thick and dense fibro-cartilaginous structure, which is firmly united to the first phalangeal bone, and but loosely

adherent to the metacarpal. It is continuous at each side with the lateral ligament, so that the three form one undivided structure which covers the joint, except on the dorsal aspect. Its palmar surface is grooved for the flexor tendons, whose sheath is connected to it at each side; the other surface, looking to the interior of the joint, is lined by the synovial membrane, and supports the head of the metacarpal bone.* In the joint of the thumb there are two sesamoid bones, one situate at each side, which are connected with its ligaments.

A *synovial membrane* is present in each joint, and invests the surface of the ligaments which connect the bones. Synovial sac.

The *phalanges are articulated with one another*,[18] on the same plan as that which obtains in the articulation between the bases of the first phalanges with the metacarpal bones; it is therefore unnecessary to repeat what has just been stated on that subject. Articulation of phalanges same as preceding.

There are some other fibrous and ligamentous structures which deserve to be noticed in this place, but not as being connected immediately with the joints; they are rather accessories to the tendons of the muscles. Thus, along the margins of the phalanges, on their palmar aspect, are attached the *vaginal ligaments*, which form sheaths for the flexor tendons, and bind these securely to the bones; they are thick and firm along the bodies of the phalanges, but over the flexures of the joints they are thin, so as not to impede the movements; their inner surface is lined by a fine membrane of the synovial class, which is reflected over the tendons, giving to the parts a smooth and shining appearance. Some other ligamentous structures. Vaginal ligaments of fingers.

The *posterior annular ligament* of the wrist is continuous with the fascia of the fore-arm, of which it may be considered a part. It extends from the extremity of the radius, at its outer border, to the inner part of the cuneiform and pisiform bones, and serves to bind down the extensor tendons. Posterior annular.

The *anterior annular ligament* is a dense fasciculus of Anterior annular of wrist.

* M. Cruveilhier (Op. cit., t. i. p. 440) considers the name "glenoid ligament" to be most appropriate to these ligaments, on the ground that they serve to continue and complete the shallow (glenoid) articular cavity of the first phalanx; the size of which he regards as otherwise disproportionately small in comparison with the head of the metacarpal bone.

fibres, extending across the carpus from the pisiform and unciform bones to the trapezium and os scaphoides, so as to form a canal, which transmits the flexor tendons of the digits, retains them in their situation, and modifies their action on the hand.

ARTICULATIONS OF THE PELVIS.

Bones that touch.

The os sacrum, considered as the common point of support of the vertebral column above, the os coccygis below, and ossa innominata on each side, is connected with each of these in the following manner :—

Sacrum to vertebra; same ligaments as for one vertebra to another;

Sacro-vertebral articulation.—The base of the sacrum is articulated with the last lumbar vertebra by means similar to those which connect the different vertebræ throughout the column ; 1, by an inter-vertebral substance placed between their oval surfaces ; 2, by the continuation of the anterior and posterior common ligaments ; 3, by ligamenta subflava connecting the neural arch of the last lumbar vertebra with that of the first sacral ; 4, by an inter-spinous ligament ; 5, by two fibrous capsules and synovial membranes for the articulating processes ; and lastly, by a sacro-vertebral ligament. All these, except the last, being similar to the connecting media throughout the column, require no farther description in this place.

except the sacro-vertebral ligament.

The *sacro-vertebral ligament* (fig. 94,[1]) extends obliquely from the tip of the transverse process of the last lumbar vertebra downwards to the depressed lateral surface at the base of the sacrum ; its form is triangular, and its fibres diverge, some joining the ligament in front of the sacro-iliac articulation.

Lumbar vertebra to hip bone by one band.

The *ilio-lumbar ligament*[2] is extended horizontally between the summit of the transverse process of the last lumbar vertebra and the iliac crest of the innominate bone ; it is inserted into the latter opposite the hinder part of the iliac fossa, where its fibres expand somewhat, so as to give it a triangular form. This is the only bond of union between the lumbar vertebræ and the hip bone.

Sacrum to coccyx, like the bodies of the vertebræ.

The *sacro-coccygean articulation* is effected, 1, by an *anterior ligament* (fig. 93,[3]), consisting of irregular fibres, placed in front of these bones, and subjacent to the rectum ; 2, by a *posterior ligament* more strongly marked, composed of fibres which descend upon the bones of the coccyx from the margin of the inferior orifice of the sacral canal ; 3, by a

thin layer of *fibro-cartilage*, which is of soft consistence, and interposed between the contiguous extremities of the sacrum and coccyx.

Coccygeal bones one to another, in same way.

The several *pieces of the coccyx are connected one to another* by a continuation of the anterior and posterior ligaments, which unite the sacrum and coccyx, and by very thin intervening fibro-cartilages. M. Velpeau* states that he has found the fibro-cartilage to be annular in shape, and that the bones were covered with cartilage towards the middle of the joint. There is, in some instances, much softness and pliancy; and a synovial membrane has been mentioned † as present in those cases in which the coccyx is freely movable.

Bony union in adult male.

In the adult male, the union between the sacrum and coccyx, and that between the pieces of the latter, is usually ossific. In the female this change most commonly does not occur till a more advanced period of life: the pieces of the coccyx unite one to another in the first place, and the joint between the sacrum and coccyx is not ossified till old age comes on. The mobility increases during pregnancy.

Sacrum and hip bone.

The *sacro-iliac articulation*, often named the sacro-iliac symphysis or synchondrosis, is formed between the lateral surfaces of the sacrum and hip-bone closely applied to one another, and connected by an irregular lamella of a cartilaginous structure, and by the following ligaments—

Fig. 92.‡

Posterior sacro-iliac ligaments very thick and short;

The *posterior sacro-iliac ligaments* consist of three or four sets of short, strong, irregular fibres, extended between the posterior rough portion of the lateral surface of the sacrum and the corresponding part of the hip-bone,—behind the articular surfaces of the bones.

* "Traité compl. de l'Art des Accouchemens," tom. i. p. 9. Paris, 1835.

† M. Cruveilhier, "Anatomie descriptive," tom. i. p. 356. Paris, 1834.

‡ The left side of the pelvis, and a part of the femur with ligaments.

Some of the fibres pass horizontally between the bones, others obliquely; of the latter, one band (fig. 92,[6]) extending downwards from the posterior superior iliac spine to the third or fourth piece of the sacrum, is described separately, under the name of (from its direction) the

Fig. 93.*

one oblique band.

oblique, or (from being situate superficially to the others) *the posterior sacro-iliac ligament*. The

Anterior ligament thin.

anterior sacro-iliac ligament consists of some thin irregular fibres (figs. 93, 94,[7]), placed at the anterior aspect of the sacro-iliac symphysis, and attached to the pelvic surfaces of the sacrum and os innominatum.

Articular cartilage.—This is a thin stratum of cartilage that fills the irregularities in the surfaces of the bones: in it there is sometimes a hollow, like that which exists in the symphysis pubis.

The sacrum and coccyx are connected with the hip-bone by the following ligaments:

Great sacro-sciatic ligament; situation,

The *posterior*, or *great sacro-sciatic ligament* (figs. 92, 93,[4]) (ligamentum sacro-ischiaticum majus,—Weitbr.), elongated, broad, and triangular, is placed at the inferior and posterior part of the pelvis, whose lower aperture it assists materially

attachments,

in closing. Its base or broader part is attached to the postero-inferior iliac spine of the haunch bone and to the side of the sacrum and coccyx; whilst its other extremity is fixed along the inner surface of the ischial tuberosity, where it expands somewhat, and sends upwards and forwards

falciform elongation.

along the margin of the ischial ramus a falciform process,

3. Coccygeal ligaments. 4. The great, and 5, the small sacro-sciatic ligaments. 6. The oblique ligament. 13. Cotyloid. 14. Ligamentum teres of hip-joint.—This sketch is inaccurate, e. g. the "small" sacro-sciatic ligament and foramen are too large; the round ligament of the hip-joint is fixed too high in the acetabulum.

* A section of the pelvis having been made, the left lateral half is seen on the inner side with ligaments: viz. 3. Sacro-coccygean. 4. Great sacro-sciatic. 5. Small sacro-sciatic. 7. Anterior sacro-iliac. 10. Obturator.

which presents one surface looking towards the perinæal space, and the other to the internal obturator muscle; the concave margin of this offset is connected with the obturator fascia. The posterior surface of the ligament gives origin to part of the gluteus maximus; the anterior is in contact with the small sacro-sciatic ligament.

Small sacro-sciatic ligament; The *anterior*, or *small sacro-sciatic ligament*,[5] (ligamentum sacro-ischiaticum minus, internum,—Weitbr.), much shorter and thinner than the preceding ligament, is attached by its base to the side of the sacrum and coccyx, where its fibres are blended with those of the great ligament; and, by its apex, to the ischial spinous process of the hip-bone. Its form is triangular, and the direction of its fibres forwards and outwards. This, the smaller ligament, has behind it the larger one; and in front, or towards the pelvic cavity, it is in contact with the coccygeus muscle.

how fixed to bone,

connections.

Sacro-sciatic foramina;—small and large, and their contents. The ischial spinous process and tuberosity and these two ligaments bound an oval interval, the *small sacro-sciatic foramen*, through which pass the obturator internus muscle, and the internal pubic vessels and nerve. Above the shorter ligament is a large oval opening, named the *large sacro-sciatic foramen*; this is bounded before and above by the posterior border of the innominate bone, and behind by the great ligament. It transmits the pyriform muscle, the great sciatic nerve, and the gluteal and ischiatic vessels and nerves. The ligaments, therefore, convert the sacro-sciatic notches of the hip-bone into foramina.

Symphysis pubis: how constructed. The *pubic articulation* (symphysis pubis) is formed by the junction of the hip-bones in the median line in front. In it there is an elongated piece of cartilage, interposed between the osseous surfaces, and connected to each; and fibrous bands or ligaments strengthen the whole.

A piece of cartilage; The *cartilage* is attached to the bony surface as indicated in fig. 93, and projects somewhat beyond the level of the bones behind. It varies in thickness in different bodies. At the back of the cartilage is an interval with smooth surfaces, which is larger in one body than in another, and is provided with a synovial-like fluid: when this space is large it reaches from the front to the back of the articulation, and divides the cartilage into two, so that each bony surface has its own cartilaginous plate. A provision is thus made for a slight degree of movement, which, however, is more perceptible in the female pelvis.

how disposed;

interval in it;

degree of movement.

Ligaments The union between the bones is strengthened by an

attachments. pit before the spine of the tibia; and by its upper extremity it is inserted into the inner and hinder part of the external condyle of the femur; hence its direction is upwards, backwards, and outwards. The *posterior ligament*[7] is attached inferiorly to the back of the pit behind the tibial spine, and superiorly to the fore part of the intercondyloid hollow, as well as slightly to the side of the inner condyle of the femur; its fibres are directed upwards and a little forwards. Its anterior surface is in contact with the last-mentioned ligament, and its posterior with the ligamentum posticum.

Posterior crucial; attachments.

Semi-lunar fibro-cartilages; situation; connections of both.

The *semi-lunar-fibro cartilages* are two crescent-shaped and flattened lamellæ, placed on the articulating surfaces of the head of the tibia, and interposed between these and the condyles of the femur. The outer border of each is thick and convex, the inner thin and concave, leaving the central part of the upper surface of the tibia uncovered. The superior surface of the fibro-cartilages is concave, and in apposition with the condyles of the femur; the inferior is flat, and rests on the head of the tibia. At their extremities they are fibrous, and are firmly fixed to the head of the tibia, whilst by the circumference they are connected with the fibrous capsule of the joint.

Both fixed to the tibia.

Internal; its shape, and attachments.

The *internal semi-lunar fibro-cartilage* (fig. 97,[8]) elongated from before backwards, is nearly of a semi-circular form; its anterior cornu is small and pointed, and is inserted into an impression at the fore and outer part of the internal articular surface of the tibia; its posterior end is attached to the inner edge of the hollow behind the spine, and is in relation with the posterior crucial ligament.

External; its shape, and attachments.

The *external semi-lunar body*[9] forms nearly a complete circle; its two cornua, fixed, one before, the other between the points of the spine of the tibia, are so close at their insertion that they may be said to be interposed between the attachments of the internal semi-lunar disc. Its external border is in contact behind with the tendon of the popliteus muscle, and is therefore separated by this from the fibrous capsule. From this fibro-cartilage a ligamentous band ascends to be inserted into the inner condyle of the femur: at one time it is in front of, and at another behind the upper attachment of the posterior crucial ligament.

Its accessory band.

external semi-lunar cartilages. 10 Transverse ligament. 11. Anterior tibio-fibular ligament.

Both surfaces of each semi-lunar fibro-cartilage are invested by the synovial membrane.

Both connected by transverse ligament, and covered by synovial membrane.

Transverse ligament.—Towards the front of the joint the convex borders of the inter-articular fibro-cartilages are connected by a slight transverse band,[10] which receives this name. Its thickness varies much in different bodies.

Synovial membrane.

The *synovial membrane*, like all similar structures, lines the contiguous surfaces of the parts entering into the composition of the knee-joint, and presents necessarily rather a complex arrangement. This complexity is increased by the existence of a small fold named *ligamentum mucosum*, which stretches across the joint, reaching from the anterior part, at some distance below the patella, backwards to the margin of the inter-condyloid fossa.

Folds of it: ligamentum mucosum.

The continuity traced.

Commencing to trace the reflections of the membrane at the border of the patella, it will be found to line the capsule, but below that bone it is separated from the anterior ligament by a considerable quantity of adipose matter. Then, reflected over the semi-lunar fibro-cartilages, it gives them an investment; and round the crucial ligaments also it forms a partial covering, enclosing them as far as their attachment. At the sides of the patella there are two slight folds, which are named "*alar*" ligaments (ligamenta alaria). By means of the ligamentous structures the membrane will be guided to the articulating surfaces of the bones at several points. Finally, ascending for some way in front of the femur, it forms a cul-de-sac between this and the tendon of the extensor muscles, and passes downwards to the margin of the patella, from which it has been followed.

Ligamenta alaria.

PERONEO-TIBIAL ARTICULATIONS.

Ends and shafts of bones connected.

The upper and lower extremities of the tibia and fibula are connected by ligaments together with synovial membranes, and the shafts of these bones are moreover united by an inter-osseous membrane.

Superior articulation.

The superior extremities of the bones present two flat oval surfaces covered with cartilage, which are closely applied to one another, and retained *in situ* by an anterior and a posterior band. The *anterior ligament* (ligamentum superius anticum) (figs. 97 [11]; 98 [1]) is a broad flat band of fibres, which passes obliquely upwards and inwards from the head of the fibula to the external tuberosity of the tibia.

Anterior ligament.

The *posterior ligament* (ligamentum superius posticum)

Posterior ligament.

Synovial bursa in front.

is covered by many muscles. A synovial bursa separates it in front from the conjoined psoas and iliacus. The bursa has been found to be continuous with the synovial membrane of the joint, through an opening in the fore part of the fibrous capsule.

Cotyloid ligament deepens and narrows acetabulum;

shape and attachment.

The *cotyloid ligament* is a fibro-cartilaginous ring (fig. 92,[13]), placed round the cavity, which serves the purpose of increasing the depth, and completing the border where this is deficient. It is inclined inwards from the point of its connection with the bone, so as to narrow the acetabulum, and as it were to embrace the head of the femur. The broader part or base of this structure is attached to the bone, and its thin edge is free ; the external surface is in contact with the capsular ligament, the internal with the head of the femur, and both are covered by the synovial membrane. Its fibres are not continued all round ; they rather pass obliquely from without inwards, over the margin of the cavity, one extremity being attached to the outer, the other to the inner surface.

Transverse ligament over cotyloid notch.

Vessels to joint beneath ligament.

At the cotyloid notch the deepening band of fibro-cartilaginous fibres is continued from side to side, so as to render the circumference complete, but some additional deeper transverse fibres are superadded in this part ; from which circumstance, as well as from the band being stretched across from one margin of the notch to the other, it is usually named the *transverse ligament*. Subjacent to the transverse portion an interval is left for the admission of the articular vessels.

Ligamentum teres, or round ;

points of attachment.

The *inter-articular ligament* (fig. 92,[14]) is not unfrequently called the "round" ligament (tapering ?) (ligamentum teres capitis femoris,—Weitbr.). It is a fasciculus of fibres, implanted by one extremity, which is round, into the fossa in the head of the femur ; by the other, which is broad, flat, and bifid, into the margins of the cotyloid notch, where its fibres become blended with those of the transverse ligament. The outer surface of this ligament is covered with a tubular process of the synovial membrane of the joint. It presents many varieties as to thickness and strength in different cases.

Synovial membrane ;

The *synovial membrane* lines the contiguous surfaces of the parts entering into the composition of the articulation, and gives them a smooth and shining appearance. From the margin of the articular surface of the femur, it may be traced along the neck of that bone to the insertion of the capsular ligament, the inner surface of which it lines as far

as the superior attachment. There it turns inwards over the cotyloid ligament, and covers the fat in the bottom of the articular cavity; and finally, guided as it were by the inter-articular ligament (which it invests by a funnel-shaped process), it reaches the head of the femur, whence its reflections have been traced.

tube for round ligament.

THE KNEE-JOINT. (FEMORO-TIBIAL.)

This is a ginglymus or hinge joint, which is formed by the condyles of the femur above, the head of the tibia below, and the patella in front; the contiguous surfaces of the several bones are covered with cartilage, and provided with a large synovial membrane. The joint is supported by ligaments at opposite sides, viz. external and internal, anterior and posterior; as well as by some bands and accessory structures in the interior, viz. two crucial ligaments, and two interposed fibro-cartilages (semi-lunar) with a transverse connecting band.

Articular surfaces,

and outline of the ligaments.

The *internal lateral ligament* (figs. 95, 96 [2]), broad and flat, connects the tuberosity of the internal condyle of the femur with the inner surface and the hinder border of the tibia. Inferiorly it is covered by the tendons of the sartorius, gracilis, and semi-tendinosus muscles, with a synovial bursa interposed; its deep surface rests on the articular synovial membrane.

Internal lateral ligament broad and long.

Fig. 95.*

The *external lateral ligament*[3] is a rounded cord-like fasciculus of fibres, shorter than the preceding ligament, which passes from the tuberosity of the external condyle of the femur to the head of the fibula. Its direction is almost vertical; its internal surface corresponds with the tendon of the popliteus muscle and the external articular vessels. The tendon of the biceps flexor cruris is divided into two

External lateral ligament round and short;

is incased by biceps;

* Figure 95 is a front view of the ligaments of the left knee-joint; parts of the femur, the tibia, and the fibula, with the patella, are discernible. Fig. 96 is a back view of the same. 1. Ligament of the patella. 2. Internal lateral of knee-joint. 3, 4. External lateral of same. 5. Posterior ligament, in connection with the tendon of the

(ligamentum fibulæ medium) descends from the extremity of the fibula, and is inserted into the middle of the external surface of the os calcis. It is crossed by the tendons of the peroneus longus and brevis muscles. 2. The anterior fasciculus (fig. 98,[6]) (ligamentum fibulæ anterius) passes obliquely forwards from the fore part of the outer malleolus to a spot on the astragalus in front of its outer lateral articular surface; it is the shortest of the three. 3. The posterior, (fig. 99,[7]) (ligamentum fibulæ posterius,) the strongest of the three ligaments, passes almost horizontally backwards from the pit on the inner surface of the malleolus towards the posterior surface of the astragalus, where it is inserted, reaching to the border of the groove for the tendon of the flexor longus pollicis.

middle to os calcis; anterior and posterior to astragalus.

Anterior and *posterior tibio-tarsal ligaments.*—In front of the joint is a thin membrane, (fig. 98,[7]) composed of irregular fibres, and extended from the border of the articulating end of the tibia to the astragalus in front of its pulley-like surface. The posterior ligament, whose chief fibres are transverse, is attached to the same bones behind the articular surfaces.

Anterior and posterior ligaments.

The *synovial membrane* lines the joint and sends upwards a process for the inferior peroneo-tibial articulation; so that this last articulation may be said to form part of the ankle-joint, as both are lined by the same synovial membrane.

Synovial membrane; extends between tibia and fibula.

ARTICULATIONS OF THE FOOT.

Bones of the foot.

The several bones of each of the divisions of the foot (tarsus, metatarsus, and phalanges,) are bound together by ligaments; and these divisions themselves are similarly united so as to form a whole.

The seven bones of which the tarsus consists may be divided into two sets: the os calcis and astragalus forming the first; the scaphoid, cuboid, and three cuneiform bones, the second. And their complicated articulations will be arranged in three divisions.—*a.* In the first will be placed the articulations of the bones of the first set, the one with the other.—*b.* The second division will contain the connections of the first with the second set.—*c.* And the last will comprise the connections of the several bones of the second set with each other.

Their articulations arranged in three divisions.

A. ARTICULATION OF THE TARSAL BONES OF THE FIRST RANGE, THE ONE WITH THE OTHER.

The astragalus with the calcaneum.—The astragalus is connected to the calcaneum by three ligaments, and two synovial membranes. The chief of the former is situate between the bones, uniting them somewhat after the manner that bivalve shells are connected by their muscle, and is named from its position the *inter-osseous ligament.* Its breadth from side to side is more than an inch; and the fibres of which it is composed pass perpendicularly between the bones, one extremity being fixed to the groove between the articulating surfaces of the calcaneum, the other to a corresponding depression in the astragalus. The *posterior ligament* (fig. 99,[6]) connects the posterior border of the astragalus with the upper surface of the calcaneum; its fibres are oblique, and its length but little more than three or four lines. The *external ligament* is a slight fasciculus, which descends perpendicularly from the outer surface of the astragalus to the external side of the calcaneum; its direction is parallel with the middle division of the external lateral ligament of the ankle-joint. It may be farther observed, that as the astragalus is wedged in between the malleoli, and as the lateral ligaments of the ankle-joint pass downwards from them to the os calcis, those ligaments must contribute somewhat to retain the astragalus in its position with regard to the latter bone.

Astragalus with os calcis.

Three ligaments; inter-osseous, the principal one.

Posterior ligament short and thin.

External ligament slight.

Security from other ligaments.

Synovial membranes.—There are two sets of articular surfaces by which the astragalus and calcaneum are in contact. The posterior one has a separate synovial sac; while the membrane which serves for the anterior articulation is continued forwards between the astragalus and the scaphoid bone.

Two synovial membranes; one special, the other common to another joint.

B. ARTICULATIONS OF THE TARSAL BONES OF THE FIRST SET WITH THOSE OF THE SECOND.

This division includes—1. The articulation of the os calcis with the cuboid. 2. The os calcis with the scaphoid. 3. The astragalus with the scaphoid.

Os calcis with cuboid.

The calcaneum with the cuboid bone.—The connection between these bones is maintained by three ligaments and a synovial membrane. The *superior calcaneo-cuboid ligament*

Superior calcaneo-cuboid ligament.

is a narrow flat band of fibres, which connects the anterior and upper surface of the calcaneum with the adjacent part of the cuboid bone. The *inferior ligament* consists of two distinct fasciculi of fibres, differing in form and attachments; of which one is superficial, the other deep-seated. The superficial part, called the *long plantar ligament* (fig. 100,[2]) (ligamentum longum plantæ), is the longest of the tarsal ligaments. Its fibres, attached behind to the inferior surface of the calcaneum as far as the anterior tubercle, pass forwards, and are attached in greater part to the tuberosity on the under surface of the cuboid bone; some of them are continued onwards, and terminate at the bases of the third and fourth metatarsal bones, after covering the tendon of the peroneus longus muscle. The *deep-seated plantar calcaneo-cuboid ligament*[3] lies close to the bones, being separated from the former by some cellular tissue. Its breadth is considerable, its length scarcely an inch. One extremity is attached to the calcaneum before the long ligament, the other (somewhat expanded) to the under surface of the cuboid bone, internal to the tuberosity.

Inferior ligament has two parts, viz.

ligamentum longum plantæ,

and deep calcaneo-cuboid.

Internal or *inter-osseous calcaneo-cuboid ligament.*—Besides the preceding ligaments there is another band of fibres, placed deeply between the bones in the sinus or pit between the astragalus and os calcis (its anterior part): these extend from the os calcis to the inner side of the cuboid.—A *synovial membrane* is present in the joint, and is necessarily reflected upon the articular surfaces of the ligaments.

Inter-osseous calcaneo-cuboid ligament.

Synovial membrane.

The calcaneum with the scaphoid bone.—This is effected by means of two ligaments, their surfaces not being in contact. Of these ligaments, the inferior, or plantar one, (fig. 100,[7]) (ligamentum calcaneo-scaphoideum inferius,—Meckel,) much the larger, passes forwards and inwards from the fore-part (sustentaculum tali) of the calcaneum to the inferior surface of the scaphoid bone. The ligament is flat and horizontal, and in contact inferiorly with the tendon of the tibialis posticus muscle, while superiorly it forms part of the fossa which receives the head of the astragalus; and it is lined by the synovial membrane, which is continued forwards from the anterior articulation of the astragalus and os calcis. The *external*, *dorsal*, or *inter-osseous ligament* (lig. calcaneo-scaphoideum externum), forms the external boundary of the cavity just mentioned. Its fibres, very short, are directed from behind forwards between the contiguous extremities of the bones. They are attached posteriorly

Os calcis with scaphoid.

Inferior ligament supports astragalus.

Attachments.

External inter-osseous,

attachments.

lge of the os calcis that separates the articular sur-
r the astragalus and os cuboides, and anteriorly to
er side of the scaphoid bone. It
eply at the anterior part of the
inus pedis) between the astragalus
calcis. In connection with it is
bundle of fibres, already described
hing from the os calcis to the
art of the cuboid.

Fig. 100.*

astragalus with the scaphoid bone. astragalus forms with the scaphoid ball-and-socket joint. The upper r articulating surface of the um, and the inferior and external o-scaphoid ligaments enter into ticulation; all these parts have a n synovial membrane. On the of the foot the astragalus is l in its situation by the liga- n astragalo-scaphoideum, a broad f fibres extending obliquely for- from the anterior extremity of the lus to the superior surface of the d bone. It is covered by the ex- tendons. The place of an inferior it to connect these bones is supplied by the cal- caphoid ligament, on which the astragalus rests. stragalus wants that security against displacement would be afforded by the attachment of its inferior to the scaphoid bone; but on the arrangement of nes and ligaments above mentioned, depends, in a easure, the elasticity of the arch of the foot, as well freedom of motion which belongs to this part of the —The *synovial membrane* of this joint is continued e anterior of the two joints formed between the os nd astragalus.

Articular surfaces; shape.

One ligament,—it is dorsal.

Calcaneo-scaphoid ligament in place of inferior one.

Synovial sac is continued from behind.

CULATIONS OF THE TARSAL BONES OF THE SECOND SET OR RANGE ONE WITH ANOTHER.

tarsal bones of the second range, viz. the scaphoid,

ligaments of the foot (plantar surface). 1. Inferior calcaneo-. 2. Ligamentum longum plantæ. 3. Deep plantar calcaneo- 4. Tarso-metatarsal. 5. Transverse ligament. 6. Lateral s of the phalangal joints.

cuboid, and three cuneiform, are connected together in the following manner.

Scaphoid with cuboid. Dorsal, plantar, and inter-osseous ligaments.

1. The *scaphoid* and *cuboid* bones are connected by a *dorsal ligament*, composed of short thin fibres, extended obliquely between the two bones; a *plantar*, situate in the sole of the foot, and consisting of transverse fibres; and an *inter-osseous* ligament, which intervenes between the bones, and is attached to their contiguous surfaces. When the bones touch, which is not always the case, they present two small articulating surfaces, that are covered with cartilage, and have an offset of the common tarsal synovial membrane.

Scaphoid with three cuneiform. Dorsal; plantar ligaments are tendinous.

2. The *scaphoid* and the *cuneiform bones* are held together by dorsal ligaments. It will be recollected that the scaphoid bone articulates with the three cuneiform by the smooth faces on its anterior surface. The *dorsal* ligaments, three in number, pass from the upper surface of the scaphoid to the first, second, and third cuneiform bones, into which they are inserted. Plantar bands are similarly disposed on the under surface of the bones, but these are continuous with, or offsets from, the tendon of the tibialis posticus.

Cuboid with external cuneiform. Dorsal, plantar, and inter-osseous ligaments. Synovial sac.

3. The *cuboid* and the *external cuneiform bone* are connected by a *dorsal* ligament, which is a thin fasciculus of fibres extended between them; a *plantar ligament*, whose fibres are transverse and rather indistinct; and a bundle of *inter-osseous* fibres connected to their neighbouring sides. Between the two bones a distinct articulation is formed by cartilaginous surfaces; it is provided sometimes with a separate synovial membrane, at others with an offset from that which belongs to the scaphoid and cuneiform bones.

Three cuneiform together; Dorsal and inter-osseous ligaments.

4. The three *cuneiform* bones are connected by transverse *dorsal ligaments* and strong *inter-osseous* fibres; but the latter are their most efficient uniting structures. A transverse plantar ligament exists only between the two innermost bones. The articulations of these bones have offsets of the synovial membrane, that lines the joint between them and the scaphoid bone.

ARTICULATION OF THE TARSUS WITH THE METATARSUS.

Articulation of the tarsus with metatarsus.

The four anterior bones of the tarsus, viz. the three cuneiform and the cuboid, articulate with the metatarsus; and as the first and third cuneiform bones project beyond the other, the anterior extremity of the tarsus is very irregular. The first metatarsal bone articulates with the internal cunei-

ı ; the second is wedged in between the first and third eiform, and rests against the middle one ; the third atarsal bone articulates with the extremity of the corre-ıding cuneiform ; and the last two with the cuboid bone. articular surfaces of the bones are furnished with syno- membranes, and they are held in contact by dorsal and ıtar, and inter-osseous ligaments.

'he *dorsal* ligaments are flat, thin bands of parallel fibres, ch pass from behind forwards, connecting the contiguous :emities of the bones just mentioned. Thus the first atarsal bone receives a broad thin band from the corre-ıding cuneiform bone ; the second receives three, which verge to its upper surface, one passing from each cunei-n bone ; the third has one from the external cuneiform e ; and, finally, the last two are bound by a fasciculus ach from the cuboid bone. The *plantar* set is less regu- ; the bands of the first and second toes are more strongly ·ked than the corresponding ligaments on the dorsal sur- ; and those of the fourth and fifth toes, which are ted by merely a few scattered fibres to the cuboid, receive port from the sheath of the peroneus longus muscle. amentous bands stretch in an oblique or transverse direc-ı from the internal cuneiform to the second and third atarsal bones, and from the external cuneiform to the fifth atarsal.

Dorsal longi-tudinal liga ments.

Plantar less regular

Oblique fibres.

'he *inter-osseous* ligaments are longitudinal in direction, have especial interest, because of the difficulty they ıld occasion in separating the metatarsus from the tarsus ›uld this operation be considered a desirable one), in con-uence of their deep position between the bones.* *a.* The *rnal* and largest of these lies to the outer side of the first eiform bone, and extends from this bone to the neigh-ring side of the second metatarsal, close to the articular face. *b.* The *external* inter-osseous ligament separates articulation of the fourth and fifth metatarsal bones from rest. It connects the outer side of the external cunei-n bone to the same side of the third metatarsal. *c.* Some es, of less strength and importance than the preceding, observable in another situation, namely, on the outer

Inter-os-seous liga-ments also longitu-dinal.

Internal inter-os-seous.

External.

* Attention was first particularly directed to these ligaments by M. 'ranc, in connection with the amputation of the foot through the o-metatarsal articulation. See "Manuel des Opérations Chirurgi-s, &c. Par J. Coster." 3ième édit. Paris, 1829.

side of the second metatarsal bone, connecting it to the middle cuneiform. These fibres, from their position, constitute a *middle* inter-osseous ligament.—The inter-osseous ligaments may be found to vary somewhat in their connections from those here stated; they may be attached at the same time to the contiguous sides of two tarsal and two metatarsal bones.

Middle is slight.

Variations.

Three synovial sacs; two special, one borrowed.

Synovial membranes.—There are three synovial membranes in this irregular series of articulations. *a.* One belongs to the internal cuneiform and the first metatarsal bone: the joint formed between these two bones is altogether separate and out of the range of the rest. *b.* Another synovial membrane is placed between the cuboid and the fourth and fifth metatarsal bones; this is isolated on the inner side by the external inter-osseous ligament. *c.* The third or middle one is a prolongation of the synovial membrane from the joint of the scaphoid and cuneiform bones, which is continued to the articulations formed between the two external of the last-named bones, and the second and third metatarsals.

CONNECTION OF THE METATARSAL BONES WITH ONE ANOTHER.

The metatarsal bones are bound together at their tarsal and digital ends; very firmly in the former, and loosely in the latter situation.

Bases of four are articulated.

The tarsal ends or bases of the four outer bones articulate with each other, having lateral articular surfaces provided with synovial membrane, and they are connected by dorsal, plantar, and inter-osseous ligaments. The *dorsal* and *plantar* ligaments are short transverse bands stretching from one bone to another, and placed in such a manner as their names sufficiently indicate. The *inter-osseous* fibres, lying deeply between the bones, occupy the non-articular parts of their lateral surfaces: they are very resistant. The articular surfaces are supplied with *synovial membrane*, which in each is continued forwards from that lining the joints formed between the bases of these bones and the tarsus. The first metatarsal does not articulate laterally with the second bone.

Dorsal, plantar,

and inter-osseous ligaments.

Synovial sac from behind.

Heads of all connected by transverse ligament.

Transverse metatarsal ligament.—The digital extremities or heads of the metatarsal bones are loosely connected by a transverse band, (fig. 100,[5]) which is identical in its arrangement with the corresponding structure in the hand,

with this exception, namely, that it is attached to the great toe, whereas in the upper member it does not reach the thumb.

ARTICULATIONS OF THE METATARSAL BONES WITH THE DIGITAL PHALANGES, AND OF THE LATTER ONE WITH ANOTHER.

Heads of metatarsal and phalanges.

The heads of the metatarsal bones are connected with the small concave articular surfaces of the first phalanges by two lateral ligaments, an inferior ligament, and a synovial membrane, which are similar in every respect to those which belong to the corresponding parts of the hand (page 216).

Phalanges together.

The articulations of the phalanges with one another are also constructed on the same plan as those of the superior extremity (page 217). In each, the bones are held in contact by two lateral ligaments (fig. 100,*) and an inferior ligament; and the surfaces are lined by a synovial membrane.

END OF VOL. I.

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